

PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE
FURTHER EDUCATION AND TRAINING (FET) BAND

by

GODFREY PISIRAI MARUMURE

Submitted in accordance with the requirements

for the degree of

MASTER OF SCIENCE IN MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION

in the subject

CHEMISTRY EDUCATION

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: DR C E. OCHONOGOR

CO-SUPERVISOR: PROF H I ATAGANA

NOVEMBER 2012

ABSTRACT

Several misconceptions show up when learners answer questions on Chemical Equilibrium during examinations. Literature from other researchers shows similar trend of misconceptions (Johnstone, 2000; Morais, Paiva and Barros, 2007; Adesoji and Babatunde, 2008) for example, 'apply pressure to the reactants' (Johnstone, 2000). This shows that Chemistry has no meaning to these learners and they end up with misconceptions as they try to memorise facts in order to pass examinations. Learners are taught before writing these examinations, but how are they taught the concepts of Chemical Equilibrium? A descriptive approach was used on an exploratory survey conducted in Thohoyandou Cluster among Physical Science (Chemistry) FET band Educators. Cluster sampling of 40 educators from 18 randomly sampled schools responded to questionnaires. Five 'well experienced' educators who have been producing 'good' results at Grade 12 NSC examinations and two Physical Sciences subject advisors were interviewed. Using Spearman Brown Split-Half statistical method a 0,891 reliability coefficient was obtained. Research results show lack or under utilisation of laboratory equipment, teaching strategies which promote rote learning. Lack of confidence of educators due to deficiency in topic content knowledge and pedagogical skills which promote conceptual understanding were identified. Problem of English language leading to communication breakdown between educator-learners and between learner-subject leading to emergency of knowledge gaps in learners. Educators consider professional development through re-training and workshops on subject content matter and teaching strategies as the way forward to improve the quality of teaching. Topic specific PCK focusing on problem-solving strategy was recommended as a means to increasing educators' efficiency in teaching and enhance learners' comprehension and achievement in Physical Science.

Keywords: Chemical Equilibrium; Content Knowledge; Dynamic Equilibrium; FET Band; Pedagogical Content Knowledge (PCK); Pedagogical knowledge; Problem; Prospect; Problem Solving; Teaching Strategy; Reversible Reaction.

Acknowledgement

I acknowledge the significant contribution of the ISTE (UNISA) staff for the support they have been giving me with special mention going to my supervisor Dr C E. Ochonogor and co-supervisor Professor H I. Atagana for guidance and encouragement. I also thank Vhembe District Senior Manager for allowing me to conduct the research in Vhembe District high schools. I thank Circuit managers, circuit staff, school principals, Physical Sciences HODs, Physical Sciences Curriculum Advisors, and Chemistry educators for Thohoyandou Cluster of schools for the different roles they played during the research. Finally, I thank Thohoyandou Technical High School for allowing me to use their facilities during the research.

Student number: **45074909**

I declare that the dissertation with the title PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FURTHER EDUCATION AND TRAINING (FET) BAND is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE

(Mr Marumure GP)

DATE

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ABBREVIATIONS

BED – Bachelor of Education

CA – Curriculum Advisor

CASS – Continuous Assessment

DE – Diploma in Education

DoE – Department of Education

DSM – District Senior Manager

ELRC – Education Labour Relations Council

FET – Further Education and Training

GCE – General Certificate of Education

GET – General Education Training

HOD – Head of Department

INSET – In-Service Education and Training

K_c – Equilibrium Constant

LO – Learning Outcome

NCS – National Curriculum Statement

OBE – Outcome Based Education

PCK – Pedagogical Content Knowledge

POE – Prediction, Observation and Explanation

POI – Process oriented instruction

SACE – South Africa Council of Educators

SC1T1 – School 1 Educator 1; SC2T1 – School 2 Educator 1

T1 – Educator 1; T2 to T5 – Educator 2 to Educator 5 respectively

Chapter One

INTRODUCTION

1.1 Background

A lot of researches have been conducted in chemical education (De Jong, Schmidt, Burger and Eybe (Unpublished); Johnstone, (2000); (Eybe and Schmidt, (2001); Gobert and Buckley, (2000); Doymus (2008); Hilton and Nakhleh (1999), Bilgin and Geban (2006) and many others, all with the aim of improving the quality of chemical education. Many people look at chemistry as a dull and not exciting subject because its teaching sometimes does not make sense to the learner (Vamvakeros, Pavlatou, and Spyrellis, 2010). This is due to the way most educators approach it, and their pedagogical content knowledge (PCK) level.

The nature of chemistry is different from other subjects as Johnstone, (2000) believes it exists in three levels which are difficult to understand at the same time. The three levels being the macroscopic, microscopic and the representational. The macroscopic level which is the observed phenomenon has to be explained through the microscopic level that involves movement, arrangement and particles' behaviour. The macroscopic and the microscopic are then translated into scientific notation which is now the representational level. The three levels are intertwined and there is need to understand how they are related. Except for experts in the subject, it is difficult to quickly move from one level to the other, therefore it should be done in stages for easy comprehension of the three levels. Many subjects exist in two levels, macroscopic and the representational level. These two levels are easy to learn and understand as there will be no overloading the memory working space (Johnstone, 2000).

Researches by educators can complement efforts of other stake holders to improve the quality of teaching so that chemistry makes sense to the learners. The practicing educators should take active part in chemistry education researches so that the results can easily be implemented in their classes with a sense of ownership (Vamvakeros, Pavlatou, and Spyrellis, 2010;). There is no need for educators to re-invent the wheel (Van Driel, Verloop, and De Vos, 1998; Bucat, 2004) with novice educators and less successful educators continue to try their own teaching methods, but apply already documented solutions to problems and prospects of teaching chemical equilibrium as proposed by educators including experienced ‘successful’ educators. Since there is an agreement that content knowledge and pedagogical knowledge for any topic is embedded in the classroom, an educator has no PCK before he teaches the topic (Mulhall, Berry, and Loughran, 2003). Sharing with peers is much easier than with superiors or non-classroom practitioners (Reed and Bergemann, 1995; Keys and Bryan, 2001) and the educator improves his methods. Taking all this into consideration, this research seeks to include educator participation in chemical education research as they reflect on the problems and prospects of teaching specific chemistry concepts of chemical equilibrium.

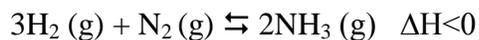
The South African curriculum offers Physical Sciences as a subject comprising physics and chemistry at the Further Education and Training (FET) band. The chemistry part comprises of three sections which are matter and materials, chemical change and chemical systems. Matter and materials deal with physics and organic chemistry. Chemical change embraces rate and extent of reactions and electrochemical reactions. Under rates and extent of reactions we find topics like rates of reaction, collision theory and chemical equilibrium (Department of Education, 2006). Major concepts being looked at in chemical equilibrium are: Open and closed system, reversible reactions, dynamic equilibrium, Le Chatelier’s principle with application to changes in

concentration, pressure and temperature, effect of catalyst on equilibrium, homogenous and heterogeneous equilibrium, equilibrium constant, K_c (DoE, 2009).

Chemical change contributes 50% of the total marks of the National Senior Certificate (NSC) chemistry examination. Chemical equilibrium forms part of chemical change and it directly contributes about 20 marks (2008; 2009 NSC Chemistry Preparatory Examinations and November Examinations; 2009 and 2010 NSC March Examination) out of a total of 150 marks which translate into 13.3% (Edwards, 2010). The concept of chemical equilibrium is well linked with other topics like electrochemical reactions and industrial processes in chemical system. Reaction conditions of different industrial processes like the Haber process, Contact process, and Oswald process are explained in terms of chemical dynamics applying Le Chatelier's Principle. In electrochemical reactions for example, $E_{\text{cell}}^0 = 0\text{V}$, in terms of chemical equilibrium, the rate of the oxidation reaction equals the rate of the reduction reaction meaning the reaction has reached chemical equilibrium. This shows chemical equilibrium has much more contribution to the chemistry examination than the 13.3% already indicated.

There is no one method which is said to be the most appropriate to teach the above concepts of chemical equilibrium therefore educators use different methods and these methods determines the level of achievement of outcomes. As different methods are being used, what are the problems in teaching these concepts? The research will focus more on the problems and prospects of teaching the concepts of chemical equilibrium.

Year in year out during marking of examination scripts, markers come across common answers with a lot of misconceptions on chemical equilibrium for example using the following chemical equation of a chemical reaction at equilibrium:



- ‘If we increase the number of ammonia the number of hydrogen gas will increase’.
- ‘Apply more pressure to the reactants and equilibrium will shift’.
- ‘When temperature reaches equilibrium it becomes constant and doesn’t change, if we add more pressure the concentration become fast’.

Previous studies have revealed that learners hold misconceptions in chemical equilibrium (De Jong et al. 1995; Johnstone, 2000; Chiu, Chou, and Liu, 2002; Bilgin and Geban, 2006; Hinton and Nakhleh, 1999; Doymus 2008). Van Driel, (2002) observed learners’ failure to conceive the dynamic nature of chemical equilibrium but viewed it as being static with ‘nothing happening’ in a system at chemical equilibrium.

Regardless of the chemistry syllabus there are common answers given by learners. The issue is, how chemical equilibrium as a topic is being taught. A variety of methods can be used in the teaching of chemistry ranging from lecturing, process oriented instruction (POI) which include inquiry- based methods, active teaching strategies like Prediction, Observation and Explanation (POE), mind mapping, modelling, problem solving, constructivist approach, context based approach. Which teaching strategies are employed by different educators for learners to end up with such misconceptions? What are the problems of teaching the concepts of chemical equilibrium? What are the prospects of teaching these concepts?

1.2 Problem Statement

When learners answer questions on chemical equilibrium during chemistry examinations several misconceptions come out. Experience from marking examinations, discussions with other chemistry educators and literature from other researchers show a similar trend of misconceptions from learners despite the different systems of education (Johnstone, 2000; Morais, Paiva and Barros, 2007; Adesoji and Babatunde, 2008; Meyer, 1993) for example ‘apply pressure to the reactants’ (Johnstone, 2000, p15). Regardless of the curriculum, misconceptions of some aspects of chemical equilibrium are becoming universal, and chemistry is fast losing meaning to learners as they end up with these misconceptions trying to memorise facts so to pass examinations. Chemistry educators do not have to normalize these misconceptions but their sources have to be identified and possible methods of intervention put in place in order not to normalize the abnormal that is not to justify the misconceptions.

Teaching as an art has to be done following certain principles in order for learners to achieve the intended objectives. When there is no proper or effective teaching an alternative conceptual framework which is different from the intended output is formed. Schmidt, Marohn and Harrison, (2006) misconceptions result from learners receiving misleading or erroneous concept information. Meyer, (1993) talks of two sources of misconceptions as misunderstanding or wrongly interpreting new information and building new knowledge on pre-existing alternative conceptual framework and the alternative conceptual framework become part of the newly formed knowledge resulting in recycling of misconceptions. Bilgin and Geban, (2006) goes on to say that misconceptions interfere with learning, therefore they need to be replaced through instruction that confront them. When learners have misconceptions their performance in the national examinations becomes poor leading to low pass rate.

Morais, Paiva and Barros (2007) believe chemical equilibrium is a learning area where learners present more alternative conceptions resulting in science becoming more difficult for them to understand and thus a great challenge for teaching. For the fact that learners write examinations after being taught and these learners demonstrate a lot of alternative conceptions on chemical equilibrium, this study investigated into the problems of teaching the topic of chemical equilibrium. This is done through identifying the problems of teaching the topic, exploring why these problems exist and their perceived effects on learners' performance. Also investigated possible solutions to these problems such that there is improvement in quality of teaching which could improve learners' performance in chemical equilibrium and chemistry in general at the FET band.

1.3 Purpose of the Study

The main purpose of the study is to:

- Investigate the problems and the prospects of teaching the concepts of chemical equilibrium at the FET band.

Specifically, it is to:

- Identify problems of teaching the topic of chemical equilibrium at the FET band.
- Explore why these problems exists.
- Discuss perceived effects of these problems on students' performance.
- Identify prospects of teaching chemical equilibrium in order to improve the quality of teaching and learners' performance in chemistry.

1.4 Significance of the study

Chemistry educators will benefit from research findings and recommendations for teaching chemical equilibrium as the problems and prospects are documented. Educators may use these as

a guide during lesson preparation and lesson delivery. When reference is made to documented problems and the prospects as well as implementing the recommendations educator effectiveness will be improved. The novice and the 'less successful' educators benefit more since chemical equilibrium is an area where many learners present several alternative conceptual frameworks. Novice educators will be able to know what to expect when they start teaching the topic and the 'less successful' educators will be able to improve their teaching by trying what other educators are doing to reduce formation of alternative conceptual framework.

Learners will also benefit from study due to improved methods of teaching which promote conceptual understanding and reduce formation of alternative conceptual framework. Learner performance will improve as a result of educators using systematic methods of teaching including improved problem solving strategy thereby creating scientific literate citizens.

The results of the study will enable Subject specialists and Department of Education (DoE) to be aware of educators' problems and prospects on the teaching of chemical equilibrium. Professional development activities are planned on needs analysis of the target group, with chemistry educators' as subjects of the study, the research findings and recommendations will guide subject specialists in coming up with intervention strategies especially for professional development.

Resource materials used by both educators and learners should enhance the teaching and learning of a particular concepts or topics to achieve the intended objectives. When resource material developers are made aware of the problems and prospects of teaching the topic, they develop the materials in line with new and better teaching strategies and content presentation. There should be a strong relationship between new teaching strategies and resource materials used.

1.5.1 Scope and Delimitation of the Study

The research focuses on problems encountered by educators when teaching the concepts of chemical equilibrium and the prospects of teaching these concepts at the FET band. Chemical equilibrium at the FET band focuses mainly on Grade 12 content as outlined in the National Curriculum Statement (NCS) 10 – 12 (Department of Education, 2003) and also in the Curriculum and Assessment Policy Statement (CAPS) document (Department of Basic Education, 2011). The problems are centred on the educators, learners and the environment.

The main concepts expected to be taught under chemical equilibrium are:

- Open and closed systems.
- Reversible reactions, explained in terms of macroscopic, microscopic and representational level including the incompleteness of the reactions.
- Chemical equilibrium explained in terms of rate of reaction and concentrations of reactants and products.
- Describe and explain chemical equilibrium dynamics, applying Le Chatelier's Principle. Change in temperature, concentration or pressure as factors affecting chemical equilibrium. Graphical representations of rate of reaction/ concentration versus time.
- Calculate and comment equilibrium constant (K_c) in terms of concentration.
- Industrial process application of chemical equilibrium dynamics. Justify optimum conditions for industrial production of the Haber process, Contact process, Oswald process and others.

On the prospects, the focus is on what the educators are doing to find solutions to the problems of teaching the above mentioned concepts of chemical equilibrium and aligning some of the

solutions to previous research findings of other researchers. This is done to improve the quality of teaching chemistry in order to improve learners' performance in the subject.

1.5.2 Research Questions

How are the concepts of chemical equilibrium taught in schools at FET Band?

What are some of the problems of teaching the topic chemical equilibrium?

What are the possible causes of these problems?

What are the perceived effects of these problems on students' performance?

What are the prospects of teaching chemical equilibrium at FET band?

1.5.3 Operational Definition of terms

Alternative Conceptions – these are conceptions generated which are parallel to the scientific conceptions. They are otherwise known as misconceptions or alternative frameworks.

Chemical Equilibrium – State of balance in a chemical reaction when the concentration of the reactants and products in a chemical reaction remain constant; Rate of the forward reaction equals the rate of the backward/reverse reaction.

Defective teaching – instructional strategies that result in generation of alternative conceptions (framework) or misconceptions.

Learner performance – Graded level of achievement of outcomes measured based on planned curriculum.

Pedagogical Content Knowledge (PCK) - Knowledge about teaching and learning that takes into account the particular learning demands of the subject matter (Bucat, 2004)

Problem – something that hinders or retards attainment of intended objectives.

Professionally Qualified Chemistry Educator – An educator, who specialised in chemistry at tertiary institution, has a qualification in pedagogy and educational didactics and teaching methodology in Chemistry.

Prospects – Expectations, views and predictions that can bring about improvement in a system.

Chapter Two

Review of Related Literature

This chapter is presented under six sub-headings including conceptual framework, nature of chemical equilibrium as a topic, problems of teaching chemistry and chemical equilibrium, Reports on previous researches on ways to improve chemistry teaching, prospects of teaching chemical equilibrium, and summary of review as follows:

2.1 Conceptual Framework

The conceptual framework for the study is on lifelong teaching practice of chemical equilibrium in particular following the current trends in chemistry education (Bolhuis, 2003; Vamvakeros, Pavlatou, & Spyrellis, 2010;). The notion of effective teaching practice is based on strategies that promote conceptual change and equip learners with skills on learning how to learn and making meaning out of their learning which is part of the constructivist view of learning (Ashcraft, Treadwell, and Kumar, 2008) and produce scientific literate citizens. A variety of conceptual change strategies have been discussed with the majority of them focusing on process oriented instruction (Bolhuis, 2003; Duit and Treagust, 2003; Treagust and Duit, 2008; Simpson and Blanchard, 2012; Maskiewicz and Winters, 2012) as an active teaching and learning strategy.

It is through effective teaching practice where learners are engaged actively in the learning process that promotes the achievement of intended objectives of producing scientific literate citizens with minimum misconceptions of chemistry concepts especially on chemical equilibrium. The strategies which promote active learning depend on how they are applied to a particular group of learners, the available resources and the environment under which teaching and learning takes place (Jonassen and Rohrer-Murphy, 1999; Crawford, 2007; Higgins, 2010).

Crawford, (2007) indicates the importance of educators understanding the essence of science, the nature of scientific inquiry and how to translate these into the curriculum. Educators' content knowledge and pedagogical knowledge contribute significantly to the level of achievement of intended objectives (Bucat, 2004). Educators should assist learners in setting learning goals and guide them in achieving those goals of which this requires a lot of skills on part of educators (Bolhuis, 2003; Ireland, Watters, & Brownlee, 2011). Minimum isolation of educators of chemistry through collaborative teaching and professional development improve educators' working conditions (Higgins, 2010).

The basis for the research study lies in the notion of 'problem' which is operationally defined in conditions and teaching strategies which does not promote learners learn how to learn the concept of chemical equilibrium and make meaning out of the concept. This is measured through indicators of lifelong teaching based on process oriented instructions, conceptual change strategies, basic working environmental conditions, material and human resources, educator's content knowledge, educator's pedagogical knowledge and educator support. The notion of 'prospects' is operationally defined in improving the quality of teaching through identifying the positive from the teaching strategies which are being used that promotes the achievement of the intended objective.

The notion of 'problems' and 'prospects' are derived from previous researches as indicated on review of related literature. Using the notion of problems and prospects research instruments were developed and collected data was analysed. Also these were used when making recommendations and identifying areas for further research.

2.2 Nature of Chemical Equilibrium as a school topic

Chemical equilibrium is integrated with several other content topics in chemistry. Chemical equilibrium is a concept which is covered in different topics of chemistry at all levels of education, secondary, college and university level. At the FET band there are several topics in Grade 10, 11 and even 12 besides being indicated as a topic (DoE, 2003). At grade 10 and 11 no mention of the concept equilibrium is made whilst teaching these topics.

Ochonogor, (1999) indicated some of the topics involving chemical equilibrium concepts as dynamic chemical equilibrium, free energy concepts, variables affecting chemical equilibrium, ionization of water and pH scale, buffer solutions, indicators in neutralization reactions, titration of acids and bases, hydrolysis and complex ion equilibrium. Different aspects are treated at different levels although without much detail being given. At times the elements of equilibrium do not come out clearly and no mention is made especially at Grade 10 and 11.

Quilez (2007) summarises all concepts of chemical equilibrium into:

- Incomplete reaction
- Reversibility of reaction
- Dynamics of reaction
- Equilibrium constant.

This summary is short and comprehensive as it tried to cover the basic concepts included in the definition of chemical equilibrium. According to Kelder, Govender and Govender, (2007);

Jones, Davies, and Mgoqi, (2007); Davids, Elferink, Maclachlan, Rens, Roos, Van Heerden and White, (2008); in the learners textbook refer to equilibrium as covered through the basic concepts at Grade 12: Open and closed system, reversible reactions, changing conditions: Le Chatelier's Principle, homogenous and heterogeneous equilibrium, equilibrium constant (K_c), solubility product (K_{sp}), common ion effect, acid dissociation constant (K_a), ionization of water, K_w and pH. Also, electrochemical reactions and chemical system include concepts on chemical

equilibrium. As guided by the curriculum requirements, almost all aspects are covered as illustrated by Ochonogor (1999) and Quilez, (2007). The main problem with most of the learners' textbooks is their failure to explain some basic chemistry concepts like 'a system' and its constituents, shift, constant and many more yet these are very important when explaining equilibrium.

2.3 Problems of teaching chemistry and chemical equilibrium

Teaching in general has some common problems. Farrant (1980) identifies training as an area that contributes towards problems in teaching chemistry. He states that educators who has not received in-service training for many years since their initial training contributes to teaching that is inefficient because it is sensitive to the needs and characteristics of growing children and ignorant of the ways in which they learn. Also lack of suitable teaching materials and accommodation reduces the effectiveness of a good deal of the teaching that goes on in school. Lastly Farrant (1980) indicate the failure by educators to change their teaching strategy in line with how children learn despite that knowledge. There is need for much more effective practical application of the educational theory that is learned during training. The problems indicated by Farrant, 1980 mainly focus on training and re-training and the effective implementation of what has been learned.

A number of researches have been conducted in Southern Africa on the teaching and learning of science according to Van den Berg in Vonk and Van den Akker, Stuart in 1991 on classroom practices in Lesotho, Engels (1993); Chapman and Snyder (1992); Fuller et al. (1991); Ogunniyi (1995); Prophet and Rodwell (1993) in Botswana, Lubben (1994) in Swaziland, Van der Laan

and Dimendaal (1994) in Namibia; Macdonald and Rogan (1990) in South Africa. There were some patterns in their findings which were expressed by Van der Laan in Vonk De Feiter, and Van den Akker (1995,p 44) as follows,

- “Insufficient confidence and mastery by many educators of both subject content and basic teaching skills (like questioning);
- Language problems for both educators and learners, English being their second or third language;
- The disjuncture between school science along often Western-based curricula and textbooks (if available) and African life outside the school environment;
- Tension between African culture (for example values about the relation between adults and children) and the spirit of inquiry and critical questioning required in school science;
- Poor material facilities (for example equipment) in schools and classrooms;
- Weak alignment of ‘innovative’ curricular aims and typical assessment and examination practices.”

Van den Laan in Vonk, De Feiter, & Van Der Akker, (1995,p 45) concluded by saying “there is a gap between improvement ideals in the various educator development projects and the current classroom practices.” This may be supported by comparing the amount of research conducted on improving the quality of teaching science (Chemistry, Physics and Biology/ Life Science) and the number of research findings which found their way into the classroom. Ottenvanger, Macfarlane, and Clegg, (2005) reflects on sustainability of In-service training and assistance for Namibia teachers (INSTANT) on the teaching of science and mathematics especially guiding them on how to implement learner-centered education. Scharberg (2005) among the challenges she discussed was crowded classrooms, learners with poor mathematics skills, and little parental support.

Textbooks are taken as a key element in the teaching of science and there is over relying on assigned text books which give learners a false impression of the nature of science (Chiappeta, Serthna, and Fillman, 1991). Some of these textbooks emphasise on vocabulary and terminology

which learners memorise giving it back in tests thinking that is what science is all about (Chiappeta, Serthna, and Fillman, 1991). There is mentioning of ideas without adequately developing the models that the scientists used to form these concepts. This now becomes a problem during teaching of concepts for an educator who over rely on the textbook.

Researches on strategies being employed to address conceptual change in learners show that some educators as well do have misconceptions on chemical equilibrium (Cheung, Ma, & Yang, 2009). Ganaras, Dumon, & Larcher, (2008) observed that some educators viewed chemical equilibrium in a systematic way by conceptualizing the chemical phenomena through the chemical reaction concept while dissociating the experimental knowledge from the theoretical knowledge. When educators have limitations in content knowledge it becomes difficult for them to demonstrate and explain the concept to the learners (Cheung, Ma, & Yang, 2009). Huddle & Pillay, (1996) consider the concept of chemical equilibrium to be abstract and being taught to learners who have not reached the stage of operational thought. The concept of chemical equilibrium is associated with the physics term 'equilibrium' and used in everyday life balancing situations (Gussasky & Gorodetsky, 1990). Learners bring to class other meanings of basic concepts of equilibrium like open and closed system, shift, constant, balance. Strategies which promote conceptual change should be used to address non-scientific ideas of learners on chemical equilibrium.

2.4 Reports of previous researches on ways to improve Chemistry Teaching

There are a variety of teaching methods and strategies that are used in the teaching of chemical equilibrium. No method can be used in isolation but they are combined depending on the objective to be achieved. In other words there is no one method which is said to be the correct

one when developing a concept but it depends on how one employs the method taking into consideration the weakness of the method and the available conditions. Due to the nature of chemistry not all methods can be used and achieve the same level of outcomes. Key elements of different teaching methods are looked at including their strength and weakness.

Johnstone, (2000) believes that chemistry exist in three forms similar to the corners of a triangle with no one corner being superior to the other. These forms of the subject are (a) “the macro or tangible: what can be seen, touched and smelt; (b) the sub-micro: atoms, molecules, ions and structures; and (c) the representational: symbols, formulae, equations, molar concentration, mathematical manipulation and graphs” (p11). De Jong and Van Driel, (2002) refer to these as the macroscopic, microscopic and the representational level. These authors concur that these should be introduced at different stages when teaching a concept as introducing them simultaneously lead to overloading workspace of the learners.

Lecture Method: It was taken as a conventional way of teaching science. Educator read notes while learners listen and at times copy down notes. There is direct transmission of information from educator to learners. Empirical studies anecdote information shows that there is overdependence on the lecture method (chalk and talk) which is in sharp contrast with the intended learner-centeredness of instruction according to Vonk, De Feiter, and Van Der Akker (1995). Due to many problems in developing countries Van den Berg et al in Vonk, De Feiter and Van Den Akker (1995) give priority to conventional teaching approaches although improved by making it more interactive and concrete through questioning and demonstrations.

Constructivist teaching: Teaching methods are based on constructivist learning theory. “Theoretical framework holds that learning always builds upon knowledge that a learner already knows (schema). Learning is filtered through pre-existing schema and more effective learning

takes place when learners are actively engaged. One primary goal of using constructivist teaching method is that learners learn how to learn by giving them the training to take the initiative for their own learning experiences”. (Eybe and Schmidt, 2001).

According to Gray, (1997), the characteristics of a constructivist classroom are as follows:

- the learners are actively involved
- the environment is democratic
- the activities are interactive and learner-centered

The educator facilitates a process of learning in which learners are encouraged to be responsible and autonomous.

“In the constructivist classroom, learners work primarily in groups and learning and knowledge are interactive and dynamic. There is a great focus and emphasis on social and communication skills, as well as collaboration and exchange of ideas”.

Some activities encouraged in constructivist classrooms are:

- ‘Experimentation: learners individually perform an experiment and then come together as a class to discuss the results.
- Research projects: learners research a topic and can present their findings to the class.
- Field trips. This allows learners to put the concepts and ideas discussed in class in a real-world context. Field trips would often be followed by class discussions.
- Films. These provide visual context and thus bring another sense into the learning experience.
- Class discussions. This technique is used in all of the methods described above. It is one of the most important distinctions of constructivist teaching methods’.

Jonassen, (1999) proposed a model for developing constructivist learning environments (CLEs) around a specific learning goal. This goal may take one of several forms, from least to most complex:

- Question or issue
- Case study
- Long-term Project
- Problem (multiple cases and projects integrated at the curriculum level)

Jonassen (1999) recommends making the learning goals engaging and relevant but not overly structured.

‘Learning is driven in CLEs by the problem to be solved; learners learn content and theory in order to solve the problem. This is different from traditional objectivist teaching where the theory would be presented first and problems would be used afterwards to practice theory.’

Anderson et al..., in Vonk, De Feiter, and Van Der Akker, (1995) do agree with the acquisition of knowledge through constructivist approach. Other proponents believe certain approaches are effective in stimulating and supporting constructivism. Verschaffel in Vonk, De Feiter, and Van Der Akker, (1995) mentions powerful learning environment, active and constructive learning of knowledge and skills should be supported by modelling, scaffolding, coaching, fading and requires a lot of the educator. Educator should possess a lot of teaching skills, dominance of subject matter and good classroom management skills. New knowledge and skills should fit in real-life context. Learners should be able to organize and motivate each other (Driver and Oldham, 1986). A variety of authors voice their concern on constructivist teaching methods (Mayer 2004; Kirschner, Sweller, and Clark, 2006) for example, “one possible deterrent for this teaching method is that, due to group work, the ideas of the more active learners may dominate the ‘group’ conclusions.” Mayer (2004) concluded that the formula constructivism = hands-on activity is a formula for educational disaster. He believes educators produce materials that require learning to be behaviourally active and not cognitively active.

Inquiry based: Here the educator proposes a set of problems for the learner to analyse and discover things by himself or herself. The educator uses guiding questions for learners to approach problem in a continuous and systematic way. Under inquiry based method fall several active teaching methods like problem solving, Process oriented instruction (POI), Prediction, Observation and Explanation (POE), word webbing, mind mapping, modelling.

Prediction, Observation and Explanation (POE): This method forms part of inquiry based method although there is a laboratory practical aspect where the learners are supposed to predict what is likely to happen and give a reason before observing the phenomenon. After observation, comparisons are made with their prediction and then scientifically explain the observed (Chiu et al., 2002). This can be an effective method although it works much better with fewer learners in class as each is supposed to make his/her prediction before observing. Only a few learners in large classes end up giving their predictions and explain the phenomenon to the class before a demonstration is carried out.

Modeling: According to Gobert and Buckley (2000), “a model is a simplified representation of a system, which concentrates attention on specific aspects of the system” (p 891). During teaching this method is used to support and reinforce other teaching methods. Usually modeling is done to enable objects, events, or ideas which are more complex look simpler and readily visible according to Gilbert in Gobert and Buckley (2000). If this is not properly applied, it may complicate the objects, events or ideas. A thorough analysis has to be done before applying the method. In modelling parameters of observation should be explicit and clear in order to reduce the formation of an alternative conceptual framework besides achieving the intended outcome.

Analogies: Newton, (2003) defines an analogy as a model drawn from one context and used to suggest an understanding of another context. Effective instructional analogy should have a strong social context (Sarantopoulos and Tsaparlis, 2004) which learners are quite familiar with. Learners holding everyday equilibrium ideas like equal masses on each side, addition to the left makes the system tilt to the left (Johnstone, 2000), using analogies with strong social context

there will be progressive “problemshift” according to Lakatos theory in (Laburu and Niaz, 2002). Lakatos Theory refer to learning taking place by accepting or rejecting the existing idea but after explaining the positive of both ideas with the new idea superceeding the old idea. There has to be a good understanding of the learners’ ideas on Equilibrium before using the analogies. Harrison and De Jong, (2005) stressed the importance of explaining where each analogy used breakdown as learners understand them in different ways and the analogy be consolidated through clearly explaining the conceptual outcome.

Problem solving: This is controversial since researchers fail to agree on the definition of 'a problem' and 'problem-solving' (Bodner and Herron, 2003). Bilgin and Karakirik, (2005) says, “Dewey (1938) define a problem as anything that gives rise to doubt and uncertainty. According to Wood, (2006) a problem is a situation where at present the answer or goal is not known. Wheatley (1984) defined problem solving broadly as what one does when does not know what to do. Problem solving requires the logical and creative thinking (Bybee and Sund, 1990). Gagne (1997) defined the problem solving as a thinking process by which the learner discovers a combination of previously learned rules that he can apply to solve a novel problem. Pizzini (1989) defined the problem solving as a method of learning as well as an outcome of learning”. Cardellini, (2006) defines problem solving as a process in which various reasoning patterns are combined, refined, extended, and invented. With these differences in definitions, learners are given what one defines as a problem to solve and refer to this as problem solving. Taconis, Ferguson-Hessler, and Broekkamp, (2001) refer to traditional approach of teaching problem solving as when learners are given many questions to work individually. Researches on the possibilities of developing problem solving skills have been conducted according to Toth and Sebestyen, (2009) where they cited Johnstone (2001), Bodner (2003), Cardellini (2006),

Johnstone and Otis (2006), Wood (2006), Cooper et al. (2008) among those researchers. Duch (1995) describes problem-based teaching as an instructional method characterised by the use of 'real world' problems as a context to learn critical thinking and acquire knowledge of the basic concepts of the course. Cardellini, (2006) explains that problem-solving is much more than substituting numbers in well-known and practical formulas; but deals with creativity, lateral thinking and formal knowledge. The problem-solving strategy involve four steps according to Poyla's model, (1957) and Nutt (1997), this comprises of: (1) defining the problem, (2) devising a plan for solving the problem, (3) carrying out the plan and (4) looking back. Blosser (1988) summarised these as retrieval from memory of pertinent information and proper application of the information of the problem. Other proponents of models for problem solving include Alex Johnstone and co-workers, the Johnstone-El Banna (1986) model (Bodner, 2003), the anarchistic model by Wheatley (1984). Bodner, (2003) discussed different models on problem solving and giving more credit to the anarchistic model by Wheatley (1984).

According to Poyla, (1957), when defining the problem, learners define the unknown and known, and use appropriate symbols. Identify the physical and chemical concepts represented in the problem. Come up with a pictorial model (where possible) of the problem. Make qualitative estimate of the value of the unknown including units.

When devising a plan to solve the problem identify the physical and chemical principles that can be used to relate the known and the unknown. If other unknown data is generated then find the additional physical and the chemical principles. Gather as much information related to the problem as possible. Try to breakdown the problem into simpler problems if possible. Any simplifying assumptions can be made.

On the third stage, using the principles write the mathematical relationships in the general form to be written. Subject of the formula is made, then substitution of numerical values into the formula. Before substitution, the numerical values should have same units. The units on the right side of the mathematical expression should be the same as on the left side. Name or symbol for the quantity calculated is properly written and correct units used. Value converted to correct significant figures.

The last stage being the look back is an evaluation of what has been done. Is the answer consistent in sign and magnitude with the qualitative estimate? Were all parts of calculation done properly? Is there no alternative way of solving the problem?

An Anarchistic Model of Problem Solving by Wheatley

- Read the problem
- Now read the problem again
- Write down what you hope is the relevant information
- Draw a picture, make a list, or write an equation or formula to help you begin to understand the problem
- Try something
- Try something else
- See where this gets you
- Read the problem again
- Try something else
- See where this gets you
- Test intermediate results to see whether you are making any progress toward an answer
- Read the problem again

- Write down “an” answer (not necessarily ‘the answer’)
- Test the answer to see if it makes sense
- Start over if you have to, celebrate if you don’t.

Extract from U.Chem.Ed, by Bodner, 2003, 7, 41

There is no much difference in the two models except that Poyla’s model is more applicable to simpler problems although it is more accurate and gives direction to the problem solver. Wheatley’s model is more general and encourages the problem solver to continue trying until a solution is found. The two models are cyclic. Modifications can be made to the Wheatley’s model by including aspects like reading the problem looking for keywords, identifying the topic to which the problem might fall under, identifying the concepts to which the key words are related and establishing any relationships between concepts and their explanations. The Johnstone-El Banna model (Bodner, 2003) focuses on the working memory capacity and the demand of the problem.

Learners should be taught for conceptual understanding to apply on problem solving although previous researches Nurrenbern and Pickering; Nakhleh; Nakhleh and Mitchell; in Toth and Sebestyen, (2009) has shown little connection between problem-solving and conceptual understanding in chemistry, learners can solve mathematical problems without understanding the microscopic (molecular) part of the problem. These learners will have problems in interpreting the significance (meaning) of the calculated values. There should be a direct link between conceptual development and problem solving strategies as Toth and Sebestyen, (2009) found that learners used algorithms instead of the conceptual understanding as a problem solving strategy yet it works more on simpler problems.

Nutt (1997) goes on explaining how to improve problem-solving skills through mastering the physical and chemical principles and being able to quickly recall them when solving a problem. Also learning from other learners how they solved the same problem, that is collaborative learning. Bodner, (2003) emphasise the importance of combining the different models like drawing diagrams which is part of Wheatley's model and educators succeed on problem-solving by reducing the amount of information to be processed avoiding overloading which is part of the Johnstone-El Banna model (Bodner, 2003).

Implementation of the problem-solving strategy requires more time especially for learners who do not easily recall physical and chemical principles. Learners should take responsibility of their own learning therefore they should be more organised. Problem-solving strategy can easily be implemented with the POE and/or context based approach as the educator only guide, probe and support learners' initiatives (Duch, 1995). Educators do not provide solutions to the problem. Bilgin & Karakirik, (2005) described a computer assisted problem solving method for use with beginning Chemistry learners. The use of computers as a teaching tool in Chemistry has not been well received by educators and is an area which still needs a lot of research on the part of educators.

Context based approach: Villalino (2009) describes context-based approach as an approach adopted in science teaching where contexts and applications of science are used as the development of scientific ideas. Villalino believes contexts are selected on the basis of their perceived relevance to learners' immediate and future lives.

Belt, Leisvik, Hyde, and Overton, (2005) believes producing context-based teaching material is only to complement other teaching activities rather than substitute them as learners respond to

contrasting learning environment, often at different times. Belt et al. (2005) shows that methods of teaching are not applied in isolation but they do complement each other. They agree with Treagust and Duit, (2008) who argue for a multiple perspective approach on science teaching and learning.

2.5 Prospects of Teaching Chemical Equilibrium

Several researchers focussed on documenting topic specific PCK (Van Driel, Verloop, and De Vos, 1998; Bucat, 2004) for chemical equilibrium. Documenting specific problems and prospects of teaching chemical equilibrium based on educators' experiences including more experienced and more 'successful' educators will help the novice and less successful educators as this will be used as case study and for reference purpose. The use of everyday life context has been seen as one way to raise learners' interest in science and to educate scientific literate citizens according to Fescher and Sumfleth (2008).

Bilgin and Geban, (2006) believes conceptual change strategies provide guidelines for designing science instruction, which takes into account the learners' existing conceptions. Learners' conceptions should be challenged through talking and scientific discussions as this foster a better understanding of the scientific concepts and the processes of science (Simpson and Blanchard, 2012). Posner, Strike, Hewson, and Gertzag in Bilgin and Geban, (2006) explains that learners must be dissatisfied with their existing ideas and beliefs before they are interested in changing them. According to Meyer, (1993) it does not only require effective teaching, active and attentive learners but also intergrating new ideas with existing knowledge. From a historical/philosophical perspective for teaching chemical equilibrium Quilez (2007) believes the four basic chemical equilibrium concepts are: 'incomplete reaction', 'reversibility', 'equilibrium

constant' and 'molecular dynamics'. He suggests using the history of chemistry to develop some of these concepts as this will encourage learners' conceptual change because of their beliefs and resistant to change. Also he believes learners hold misunderstanding parallel to some of the ideas of the 19th century scientists. The methods used to change the ideas of those scientists are the same that can be used although taking the technological development into consideration. Focussing on the reconstruction sequence for teaching the main concepts, concepts to be taught as a unit where each concept is used to develop the next concept. During the process, the Johnstone (2000) model of chemistry existing as corners of a triangle may be applied which are the 'macro, the micro and the representational levels'.

Modelling through analogies can be an effective method although a lot of caution has to be taken as most of them are two dimensional yet because of the nature of chemistry they are supposed to be three dimensional, Johnstone (2000). The two dimensional analogies can be a source of formation of an alternative concept. Harrison and De Jong, (2005) proposed the use of analogies in teaching the concepts at Grade 12 with the "school dance", the "sugar in a teacup", the "pot of curry" and the "busy highway" being the key analogical models. The main emphasis was placed on the educator clarifying the limitation of each model, that is where it breaks down, of which this is rare with educators. Most educators view analogical models as being perfect yet they may create alternative conception. When using analogical models the educator should be explicit in relating the analogical model with the concepts being represented because the level of translating the analogical model into a scientific concept differ with each learner (Harrison and De Jong, 2005). Sarantopoulos and Tsaparlis, (2004) emphasise the use of analogies with a strong and familiar social context. Modelling can be supported with activity based experimental demonstration for conceptual development and understanding.

Hurd in Vonk, De Feiter and Van der Akker (1995) said “Learning to learn seems to be the only common goal in numerous efforts around the world in revising school science curricular”. Proponents put forward ideas of changing the teaching of science/ chemistry without clearly defining how the educator has to do it. Effective In-Service Education and Training (INSET) on the proposed new teaching strategies have to be put in place. Loucks-Horsely, Hewson, Love and Stiles in Jeanpierre, Oberhauser and Freeman (2005) defined seven principles of effective science educators’ professional development. These principles include a well-defined image of effective classroom learning and teaching opportunities for educators to build knowledge and skills, modelling the strategies educators will use with learners, building a learning community, supporting educators as leaders, providing links to other parts of the education system, and providing for continuous assessment and improvement. As educators are self directed and know what they want to learn they have to be consulted. Keys and Bryan (2001) says, “The efficacy of the reform efforts rests largely on the educators, their voices need to be included in the design and implementation of inquiry based curriculum”. These sentiments were echoed by Vamvakeros, Pavlatou, and Spyrellis, (2010), with King, (2007) emphasizing the incorporation of educators’ beliefs for conceptual change.

Bucat, (2004) explanation on the need for documented topic specific PCK for each particular chemistry topic are also valid for documenting problems and prospects of teaching specific chemistry topics. He made reference to other disciplines like chess players, lawyers and architects who learn from documented case studies who exhibits skills from masters in fields. Masters in teaching specific chemistry topics when they retire or die, they retire or die with their skills and knowledge. The novice educators has no where to refer to therefore we need to tap into the knowledge of subject experts for the benefit of the novice educators.

2.6 Summary of Review of Literature

A conceptual framework for the study is lifelong teaching practice of chemical equilibrium following the current trends in chemistry education. Effective teaching practice is based on strategies that promote conceptual change and equip learners with skills on learning how to learn and making meaning out of their learning. The notion of ‘problem’ and ‘prospect’ were addressed including the basis of the research. On nature of chemical equilibrium as a school topic was analysed from previous researchers’ point of view and the learners’ textbooks. The strength and weakness of some textbooks were spelt out like not explaining important terms like system, shift, stress and balance. The concepts of chemical equilibrium were summarised into incompleteness of reaction, reversibility of reactions, chemical dynamics and equilibrium constant (K_c). Most researchers had almost the same summary.

The third aspect reviewed were the problems of teaching chemistry and chemical equilibrium. Some of the problems spelt out by previous researchers are lack of In-service Education and Training applying teaching methods without considering how best the learners learn. Most researches in Southern Africa has shown similar trend with language problems for both educators and learners, methodological problems. Also low mathematical skills in learners identified as an obstacle in the teaching of chemistry. Are these problems also faced by educators when teaching the concepts of chemical equilibrium?

Fourthly, reports from previous researches on ways to improve chemistry teaching. Most of the researches focused on active teaching strategies which included process oriented instruction like POE, modelling, constructivism, context based strategy, problem solving. Researches focused on teaching the learner how to learn. Most of the active teaching strategies are trying to promote independent or collaborative learning by the learner. The educator plays the role of the

facilitator, only guiding the learners but not providing solutions to problems. Applying these strategies needs a lot of skills from the educators. Are educators in schools applying these teaching strategies? Do educators have the skills to apply these strategies in teaching concepts of chemical equilibrium? What strategies are educators employing when teaching concepts of chemical equilibrium?

Chapter Three

RESEARCH METHODOLOGY

This chapter is sub-divided into seven sections which are research design, population of study, sample and sampling technique, Instrumentation and its validation. Reliability of instruments, methods of data analysis and ethical considerations are covered.

3.1 Research Design

The design used in the study is a simple descriptive approach. An exploratory survey was conducted in Thohoyandou Cluster of circuits amongst Physical Science (Chemistry) FET educators. Some characteristics of the survey which led to it being chosen as compared to the action research, ethnographic research or case study are (Cohen, Manion and Morrison, 2008):

The design enables one to gather standardised information when using same instruments and questions for all participants. It provides descriptive, inferential and explanatory information. A mixed method of qualitative and quantitative nature was used in this study which involved the application of varied questions like multiple choice, closed questions and open ended questions to collect data. Also an interview schedule was used to collect further data. Piloting and revision of instruments assisted in generating more accurate instruments. Collected data were generalised and also patterns in responses were observed among the targets of focus. The mixed method used enabled the researcher to triangulate the results of quantitative and qualitative data with each other to ensure clearer positions of the problems and prospects of teaching chemical equilibrium and proffer useful recommendations and suggestions.

3.2 Population of the study

Population of the study was comprised of one hundred and twelve (112) chemistry (physical science) educators at the FET band in Thohoyandou Cluster of circuits in Vhembe District of

Limpopo Province of the Republic of South Africa and two Physical science subject advisors in the cluster. Thohoyandou is a small town in Vhembe district of Limpopo Province. Thohoyandou cluster comprises of five circuits. Each circuit has an average of nine public secondary schools. The total number of Public schools offering Physical science at FET band is forty-eight (48). The cluster has a diversity of public schools ranging from former ‘model A’ schools, those which perform very well in National Examinations, ‘average’ schools and the below average schools, the zero percent schools as labelled in some quarters. The schools give a normal distribution, where there are few good schools, many average and a few bad schools which is the case with the Republic of South Africa as a country. This allowed the generalization of the research results across the spectrum. The population is made up of educators who attended different institutions of higher learning and with different number of years of experience. There was gender mixture. Two subject advisors form part of the population since these are the people directly in contact with subject educators and schools in terms of teaching and curriculum requirements of the subject.

3.3 Sample and Sampling Technique

Random sampling of schools was done by giving schools equal chances of being selected. All public schools in the Thohoyandou Cluster of circuits offering physical sciences were given numerical codes after being arranged in alphabetical order. The same codes were written again on small cards which were then put in a hat for a draw. A draw was conducted by an independent person in order to increase the reliability of results of the sample. A total of eighteen schools were drawn from the hat, using cluster sampling, each school having about two or three chemistry educators, an average of forty (≈ 40) FET chemistry educators representing

35.7% were the subjects of the research project. Through purposive sampling five experienced 'successful' educators were interviewed. Through purposive sample, two subject advisors for Physical Science Thohoyandou cluster of circuits formed part of the research sample.

All educators were given equal chance of being selected through their school to participate in the exercise as the researcher assumed all the educators are the same teaching Chemistry at FET. This assumption was made on the ground that according to ELRC Minimum Specialist Requests for Basic Teaching Qualifications National Education Policy Act 27 of 1996 all educators should have (see Appendix 1) to qualify to teach the FET band.

3.4 Instrumentation:

Research instruments used in the study are questionnaire and interview schedule. The questionnaire was chosen because it is easy to administer and any number of people required by the researcher can respond to it. Depending on the length of the questionnaire a lot of questions can be responded to. It has advantages to both the researcher and the subjects as the subject responded the questionnaire at his/her own time and own pace. Also a questionnaire was chosen due to its high response rate which was 75.9%. Semi-structured interviews were conducted using an interview schedule. The interview schedule was developed in line with the questionnaire so that all aspects on the questionnaire will be addressed although in detail. Semi-structuring the interview was to collect only relevant data for the research.

3.4.1 Questionnaire design

This was done in three stages: First, second and third draft in order to achieve valid and reliable instrument. Questionnaire items were formulated in line with the research problem and they are designed to address the research questions.

The questionnaire consists of items designed in different formats. Questionnaire items include, scales of data, three dichotomous questions (Q1, 8, 23), four multiple choice questions (Q2, 3, 5, 11), one rank ordering (Q10), thirteen open ended questions (Q9, 13, 15, 16, 19, 20, 21, 22, 26, 27, 28, 29, 30), eight closed questions (Q4, 7, 12, 14, 17, 18, 24, 25), one matrix question (Q6). Questions of different format in a questionnaire reduce boredom when responding.

3.4.2 Development of Interview Instrument

Interview schedule was used because of the following reasons according to Patton in Cohen et al. (2008:p 353):

Characteristics of the interview guide:

Topics and issues that were to be covered were specified in advance, in the form of an outline; interviewer decides sequence and working of questions in the course of the interview.

Strength of the schedule:

The outline increases the comprehensiveness of the data collected and it makes data collection process somewhat systematic for each response. Logical gaps in data can be anticipated and closed. Interviews remain fairly conversational and situational.

Weakness of the schedule:

Important and salient topics may inadvertently be omitted. Interviewer flexibility in sequencing and wording of questions can result in substantially different responses thus reducing the comparability of the responses.

Based on the above, the strength outweighs the weakness and caution was taken on the sequencing and wording of questions to ensure a proper usage of the interview schedule for a semi-structured interview.

3.4.3 Validation of instrument

3.4.3.1 Face Validity and Content Validity

The researcher distributed the questionnaires to five colleagues for review. Four of the colleagues hold masters degrees (MEd - 2, MSc - 1 and MPhil - 1). The colleagues completed the questionnaire with comments and recommendations. Also time to complete the questionnaire was taken into consideration. The questionnaire was reviewed to come up with a second draft. This was done to check the time required to complete the questionnaire and to identify areas of weakness like the phraseology, spellings, grammar, and ambiguity. Secondly, pre-testing provided the basis for generating new questions and also designing the second draft. This also included rephrasing of questions; reducing the number of questions especially open ended questions; altering the sequencing of questions and reducing the length of the questionnaire. After analysing the questionnaire questions were then modified following recommendations made by the respondents. Eleven questionnaires were distributed to people and ten of them were returned giving 91% retention. Partially completed (less than 85%) questionnaires, were not considered for analysis. The completed questionnaires' responses were transcribed to a data collection schedule.

Rephrasing of items and breaking down questions into simpler items followed the recommendations the validations. The research problem is divided into research questions. There is sub-division of research questions on questionnaire so that relevant data is collected and also the questions become easy to understand. Some of the recommendations made were to remove questions leading to unnecessary data like where and when professional qualifications were obtained. Question on lesson preparation was changed from open ended to multiple choice this provides statistical data. Text books for learners to be written separate from the educators'

and this assist in assessing the sourcing of information by educators. Item 23 was changed from open ended to dichotomous to get discrete data which is more accurate. Item 20 dealing with the causes of the problems of teaching the concepts and item 22 on solutions to the problems, and prospects of teaching the concepts of chemical equilibrium were added to the questionnaire. The original item 28 was broken down into 28 and 29 since the question was long and people had problem in answering it.

3.5 Reliability of the Instrument

Codes were used to identify schools and educators to reduce bias towards particular schools and educators. Based on the pilot study carried out, data collected from the ten respondents to the questionnaires were analysed. The items were divided into two equal numbers, odd numbers and even numbers on the questionnaire. The reliability of instruments tested through the Spearman Brown Split-Half statistical method giving a 0,891 coefficient which was acceptable.

3.6 Administration of the Instrument and Data Collection

54 questionnaires were distributed to 18 schools through the Circuit Office in envelopes (3 questionnaires in each envelope) addressed to the school principal. On each questionnaire a school code and educator number is indicated for example SC5T2 meaning on the list, this is school number five (5) and the questionnaire is for educator number two (2). Allocating codes on questionnaire assisted in controlling the questionnaire returned, and it became easy to make a follow-up.

After the forms had been completed these were returned to the circuit office where the researcher collected them. 41 of the 54 questionnaires were returned giving a retention rate of 75.9%.

From the 18 schools selected school SC7 returned all questionnaires without being completed showed no interest in participating therefore it was replaced by school SC15 which was randomly selected from the population to maintain a sample size of 18 schools. First distribution of questionnaires was given a two weeks time frame for schools to return the questionnaires from the date they were left at the circuit office but this produced a very low retention of questionnaire. A follow up letter to the school principals was written after a month. This yielded positive results as more questionnaires were returned giving a final retention of 75.9%. Only one questionnaire returned was rejected as less than 85% of the items on the questionnaire was attempted.

School visits to arrange for interviews were made after letters requesting for interview had been sent to the educators through the Circuit Offices. Date, time and venue for the interview were agreed and interview schedule was made available to the prospective interviewee. Also interview expectations were discussed as contained in the prepared outline. There were mixed feelings on data capturing methods during interviews. The two curriculum advisors preferred not to be audio recorded therefore a pen and paper method was used. Their interviews were short (\approx 30 minutes) although all important questions were addressed, this was because the subject advisors were sighting large volume of work as they were busy with CASS moderation for the end of the year.

Five educators were interviewed, three were audio recorded, T1, T2 and T3 (Educator 1, Educator 2 and Educator 3 respectively) while the other two educators T4 and T5 (Educator 4 and Educator 5 respectively) pen and paper method of data recording was used. T4 and T5 were uncomfortable being audio tapped. Due to the differences in data capturing methods, there were

some differences in data collected. The audio- recording gathered more detailed data than the pen and paper method although data obtained still remained valid and reliable since the same interview schedule was used. Several follow ups were made until the educators returned the completed questionnaires due to several challenges were encountered for example data collection postponed due to Public Service industrial Action during the month of August and September 2010.

3.7 Control of External variables

Appendix 1: Minimum requirements for educators to teach the FET (Grade 10 - 12) on National Education Policy Act 27 of 1996 was used to establish if the participating educators qualify to teach chemistry at the FET band. Working with chemistry specialists allowed the researcher to generalize to the wider population as the sample is representative. The research conducted over a three year period thereby ignoring the effects of social change and process.

3.8 Method of Data Analysis

Qualitative data analyses involved organising, accounting for and explaining the data in stages. All data were analysed using the Statistical Package for Social Sciences Version 18 (SPSS) computer software.

3.9 Ethical Considerations

The following were taken into consideration during the study:

Deception: before the study was conducted the researcher explained why the research was necessary.

Privacy and Voluntary Participation: as research always invades people's privacy, it was important for the researcher not to force the participants, they were persuaded to participate. The respondents were informed of the positive and the negative aspects or consequences of the study.

Anonymity: to avoid any bias response, it was important to convince the participants that the responses to the questionnaire and the interview will be respected and hence the use of the code system to increase anonymity of the participants.

Confidentiality: the participants' information was treated with confidentiality guided by the official Secrecy Act and professionalism.

Ethical Clearance: Ethical clearance was requested and was granted by the UNISA Research Ethics Review Committee (see Appendix 11).

Chapter 4

Data Analysis and Presentation

Data collected through questionnaire is analysed using SPSS. Descriptive methods of data presentation such as frequency tables, bar graphs, pie charts and cross tabulations are used. In some cases the Spearman rho correlations are done.

Responses from 40 respondents out of the 41 received were analysed. One of them was rejected because less than 85% of the items were responded to. This gives a response rate of 75.9%. The 40 respondents were made up of 10 female and 30 male Chemistry educators. The 40 respondents have their duty posts across rural, through semi-urban to urban schools. 18 of them teach in the rural schools; 16 others teach in the Semi-urban/ Semi-rural and the rest 6 teach in the urban schools. The responses of the five sampled 'well' experienced, producing 'good' results at NSC Grade 12 examinations and two curriculum advisors who were interviewed were also analysed.

Table 1 and Table 2 show the diversity of the sample in terms of gender distribution, age, qualifications and working experience.

Table 1: Gender and Age Distribution

	Age						Total
	26-30	31-35	36-40	41-45	46-50	Above 50	
Gender Female	2	3	1	3	0	1	10
Male	2	3	4	18	3	0	30
Total	4	6	5	21	3	1	40

The responses are from 10 female and 30 male educators. 21 of the respondents are between 41-45 years old followed by the 31 – 35 years (6) age group and then 36 – 40 years. Only one respondent is above the age of 50 years.

Table 2: Age, Experience and Qualifications Cross tabulation

Qualifications			Experience					Total	
			0-5	6-10	11-15	16-20	21-25		Above 25
NC	Age	41-45				1	1		2
	Total				1	1			2
Diploma	Age	36-40			1	0	0	0	1
		41-45			1	2	1	0	4
		46-50			0	0	0	1	1
		Above 50			0	0	0	1	1
	Total				2	2	1	2	7
ACE	Age	26-30		1		0	0		1
		36-40		1		0	0		1
		41-45		0		4	0		4
		46-50		0		0	1		1
	Total			2		4	1		7
B.ED	Age	26-30	2	1	0	0	0		3
		31-35	0	0	1	0	0		1
		36-40	0	0	0	1	0		1
		41-45	0	0	1	3	2		6
		46-50	0	0	0	0	1		1
	Total		2	1	2	4	3		12
BSc+ GCE	Age	31-35	1	1		1			3
		41-45	1	0		0			1
	Total		2	1		1			4
BSc.Ed	Age	31-35		1	0	1			2
		36-40		1	1	0			2
		41-45		0	1	1			2
	Total			2	2	2			6
MSc.Ed	Age	41-45				1			1
	Total					1			1
MPhil	Age	41-45				1			1
	Total					1			1
Grand Total			4	6	6	16	6	2	40

Majority of respondents hold B.Ed (12) degrees followed by holders of Diploma in Education and Advanced Certificate in Education (ACE) (7). Those with Bachelor of Science in Education are six and with Bachelor of Science with Graduate Certificate in Education are four (4). 40% of respondents have teaching experience of between 16 – 20 years. Only 10% have teaching experience of 0 – 5 years and are holders of B.Ed and BSc + GCE qualifications. Educators who taught for over 25 years make up 5% of the sample and are holders of Diploma in Education.

Table 3, Table 4, Table 5 and Table 8 below show the environmental conditions in which the educators operate. The tables indicate the number of learners per class, number of learners attended to by individual physical sciences educator and the material resources at the educators' disposal for teaching.

Table 3: Enrolment of Learners per Grade

GRADE	No of Teachers	TOTAL No. LEARNERS	TOTAL No. CLASSES
10		4974	95
11		4364	89
12		3773	76
TOTAL No.	40	13111	260
Average learners per class		51	

The above Table shows that 40 chemistry educators teach a large number of 13111 learners bringing the Educator: Learner ratio to 1:328 (Total number of learners divided by number of educators: $13111/40= 328$). Each class has an average of 51 learners (Total number of learners divided by total number of classes: $13111/260= 51$). Work load of educator is high as he will be working with an average of seven classes of different arms (Number of learners per educator

divided by number of learners per class: $328/51= 7$). This is a pointer to several problems that militate against the teaching and learning of Physical Sciences particularly chemistry.

Table 4a: Laboratory and Apparatus Cross tabulation (Availability of Space)

Laboratory	Total
No Laboratory Space	21
Yes Laboratory Space	19
Total	40

Table 4b: (Availability of Apparatus and Chemicals)

		Apparatus			
		My School has Nothing	My School has Not Enough	My School has Enough	
No of Educators	16	15	9		40

Table 4a shows that out of the 40 respondents, 21 of them came from schools with without laboratory spaces and the rest 19 agreed to have laboratory space with most of them ill-equipped (Table 4b). Only 9 (22.5%) of the respondents came schools having enough apparatus and chemicals for the content requirements of chemistry (including chemical equilibrium) of the FET curriculum statement. In other words, 77.5% of the respondents came from schools without or with inadequate apparatus and chemicals for effective teaching of chemical equilibrium and chemistry in general. This is a great problem that needs urgent attention.

Table 5: Correlations between school, Laboratory and Apparatus

			School	Laboratory	Apparatus
Spearman's rho	School	Correlation Coefficient	1.000	.376*	.340*
		Sig. (2-tailed)	.	.017	.032
		N	40	40	40
	Laboratory	Correlation Coefficient	.376*	1.000	.683*
		Sig. (2-tailed)	.017	.	.000
		N	40	40	40
	Apparatus	Correlation Coefficient	.340*	.683*	1.000
		Sig. (2-tailed)	.032	.000	.
		N	40	40	40

*. Correlation is significant at the 0.05 level (2-tailed).

Spearman's rho correlation coefficient analysis at $p < 0.05$ level of significance which is 2-tailed was done. Correlation at $p < 0.05$ significance level means there is a probability of 5% occurring by chance and the other 95% are obviously true. Table 5 above shows high correlations of the school with laboratory and apparatus having Correlation coefficients of .376 and .340 respectively. It also shows the high relationship between laboratories and apparatus with .683 correlation coefficient value. This implies that for a laboratory to fully perform its expected function in a school, it must adequate and appropriate apparatus for effective teaching of chemistry and physical science in general.

The analysed variables at $p < 0.05$ significance level which is 2-tailed are statistically significant since their correlation values are greater than their critical values for example correlation between the type of school and availability of apparatus has a critical value of .032 which is less than .050. A correlation of .340 is much higher than the critical value, .032. The strongest correlation is between availability of laboratory and availability of apparatus since the critical value of .000 is much higher than the critical value of .683. This shows great disparities between schools with laboratories and those without laboratories as those with laboratories do have more apparatus to use as compared to those without laboratories.

Table 6: Distribution of Confidence of Educators on teaching concepts of equilibrium

	Very comfortable	comfortable	uncomfortable	Very uncomfortable
Reaction incompleteness	15	20	4	0
Reversibility of Reaction	18	19	2	0
Chemical Dynamics	20	15	4	0
Equilibrium constant	22	10	5	1

The confidence level of educators to teach the concepts of chemical equilibrium is high as most of them indicated that they are very comfortable or are comfortable (Table 6). Only one educator expressed that he is very uncomfortable in teaching equilibrium constant.

Table 7: Correlations between Educators' Confidence of Teaching Basic Concepts of Chemical Equilibrium

			Reaction Incompleteness	Reversibility	Chemical Dynamics	Equilibrium Constant
Spearman's rho	Reaction Incompleteness	Correlation Coefficient	1.000	.777*	.688*	.513*
		Sig. (2-tailed)	.	.000	.000	.001
		N	37	37	37	37
	Reversibility	Correlation Coefficient	.777*	1.000	.708*	.446*
		Sig. (2-tailed)	.000	.	.000	.004
		N	37	40	40	40
	Chemical Dynamics	Correlation Coefficient	.688*	.708*	1.000	.752*
		Sig. (2-tailed)	.000	.000	.	.000
		N	37	40	40	40
	Equilibrium Constant	Correlation Coefficient	.513*	.446*	.752*	1.000
		Sig. (2-tailed)	.001	.004	.000	.
		N	37	40	40	40

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7 above shows that the correlation coefficients of the confidence levels of teaching basic concepts of chemical equilibrium are statistically significant. All variables have positive correlation at $p < 0.05$ significance level. The strongest correlation is between reaction incompleteness and reversibility of reaction at 0.777. The weakest correlation is between reaction reversibility and equilibrium constant at 0.446 and being the only correlation below 0.500. The results show a high degree of association of the confidence of educators to teach the basic concepts of chemical equilibrium.

Table 8: Educators and Learners' Text books

Educators' textbooks	Frequency	Learners' textbooks	Frequency
Oxford Successful	11	Oxford Successful	9
Physical Sciences Explained	6	Physical Sciences Explained	5
Physical Sciences Study and Master	24	Physical Sciences Study and Master	25
Focus on Physical Sciences	13	Focus on Physical Sciences	10
Shutters Physical Sciences	3	Shutters Physical Sciences	2
Millennium Series Physical Sciences	1	Millennium Series Physical Sciences	0
Physical Sciences for the Classroom	1	Physical Sciences for the Classroom	0
Physical Science SPOT ON	6	Physical Science SPOT ON	5
Viva Physical Sciences	0	Viva Physical Sciences	2
Physical Sciences Study Guide	0	Physical Sciences Study Guide	1
Average books per educator	2	Average books per school	1

It is clear from Table 8 that learners and educators use the same textbooks as source of information. An average of 2 text books is used by each educator. The `Physical Sciences Study and Master` is the most frequently used by both educators and learners followed by the `Focus on Physical Sciences` and Oxford Successful`, respectively.

The need to consult many text books is uppermost in Table 9 with more than 50% of the respondents agreeing. They reasoned that many books are not clear in presentation or they do not have enough information that cover questions which come in the examinations especially the higher order questions. Only 28% of educators are contend with the text books saying they cover basic content according to the requirements of the syllabus.

Table 9: Textbook for Educators, Text book Satisfaction and Comments Cross tabulation

Comment			Textbook Satisfaction			Total
			Not Satisfied	Slightly Satisfied	Satisfied	
Not clear	Textbook Educators	Only one book	3	0		3
		Two books	6	1		7
		Three	3	0		3
	Total	12	1		13	
Do not address exam questions	Textbook Educators	Two books	3	6		9
		Three	2	0		2
	Total	5	6		11	
Cover basic concepts	Textbook Educators	Only one		0	1	1
		Two books		1	3	4
		Three		2	3	5
		Five		0	1	1
	Total		3	8		11

Comments on textbooks which are being used by the educators and the number of textbooks used to teach the concepts of chemical equilibrium are indicated in the above table. Only one educator use up to five different text books for lesson preparations and is satisfied. In all, eight (8) out of the 40 educators are satisfied with the text books they use. Despite not being satisfied, three of the educators use only one textbook for their preparation and six others use two textbooks as resource materials. Eleven of the educators were not satisfied since the text books do not cover examination questions. Thirteen of the educators believe that the textbooks they use are not clear, yet three educators use only one textbook for their lesson preparation and teaching. The other seven and three educators of the thirteen use two and three textbooks respectively.

Table 10: Correlations between lesson Preparation, Educators' Textbooks, Textbook Satisfaction and Comment level

			Preparation Time	Textbook Educators	Textbook Satisfaction	Comment Level
Spearman's rho	Preparation	Correlation Coefficient	1.000	.262	-.142	-.018
		Sig. (2-tailed)	.	.112	.382	.916
		N	40	38	40	36
Textbook Educators	Textbook Educators	Correlation Coefficient	.262	1.000	.077	.312
		Sig. (2-tailed)	.112	.	.644	.068
		N	38	38	38	35
Text book Satisfaction	Text book Satisfaction	Correlation Coefficient	-.142	.077	1.000	.830*
		Sig. (2-tailed)	.382	.644	.	.000
		N	40	38	40	36
Comment Level	Comment Level	Correlation Coefficient	-.018	.312	.830*	1.000
		Sig. (2-tailed)	.916	.068	.000	.
		N	36	35	36	36

*. Correlation is significant at the 0.05 level (2-tailed).

Correlation of four variables which are time taken by educators to do their lesson preparation, the number of textbooks used by the educators during the lesson preparation, whether the educators are satisfied with the textbook(s) they use and comments made by educators regarding the content of the text books they use was analysed at $p < 0.05$ significance level which is 2-tailed. The results in Table 10 above show that the only variables which are statistically significant are textbook satisfaction and comments made by educators on the textbooks they use. The critical values for the rest of the correlation are higher than the significant levels meaning that their chances of happening were less than 95% therefore the correlation are statistically non-significant. For example correlation between lesson preparation time and textbook satisfaction of educators has a critical value of 0.382 which is much higher than 0.05 significance level making the correlation statistically non-significant. This means there is no degree of association between these variables with a negative correlation coefficient of -.142.

Table 11: Lesson Preparation and Strategies Cross tabulation

Lesson Preparation Time (Minutes)	Strategies							Total
	Lecture	Question and Answer	Group Discussions	Experimental/ Demonstration	Learner Centred	Discovery	Problem Solving	
0-10	0	0	0	1	1	0	0	2
11-20	0	0	1	2	0	0	0	3
21-30	0	4	4	2	2	0	2	14
31-40	2	2	1	1	0	1	0	7
Above 40	2	0	3	7	0	1	1	14
Total	4	6	9	13	3	2	3	40

Table 11 shows a comparison of the strategies used by educators and the time they take to prepare for their lessons. About 13 of the 40 educators use experiments/demonstration; and of the 13, seven of them take more than 40 minutes preparing for their lessons. 28 of the 40 educators take between 21 – 30 minutes and above 40 minutes in equal halves. It is during

experiments or demonstration where the educators take more time during preparation of their lessons, with seven of the 13 educators taking more than 40 minutes to prepare.

Figures 1 and 2 representing data from questionnaires are addressing the research question on the methods/ strategies used by educators to teach the concepts of chemical equilibrium in schools.

Educator	Lesson procedure on concept of chemical equilibrium
1	<p>Le Chatelier's Principle: Step 1: learners state factors affecting equilibrium position in groups.</p> <p>Step 2: Teacher explain underlying ideas of principle.</p> <p>Step 3: Experiments in groups to determine effect of concentration and temperature on equilibrium position using $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$ equilibrium</p> <p>Step 4: Each group to report back to the class members.</p> <p>Step 5: Teacher to summarise the effect of temp and concentration on equilibrium position</p>
2	<p>Step 1. Ask learners to define reversible reaction, concentration, pressure, catalyst.</p> <p>Step 2. Teacher-learner discussions on chemical equilibrium</p> <p>Step 3. Demonstrations illustrating chemical equilibrium and effects of concentration, pressure and temperature on chemical equilibrium.</p>
3	<p>Step 1. Educator to explain what chemical equilibrium is.</p> <p>Step 2. Put learners in groups to work on chemical equilibrium problems.</p> <p>Step 3. Educator seek learners' understanding of chemical equilibrium</p> <p>Step 4. Educator explain deeper the concept of chemical equilibrium.</p>
4	<p>The educator to explain to learners what is chemical equilibrium. If we add more reactant, then we favour the forward reaction. When we cool up the products, then the backward reaction will be favoured.</p>
5	<p>Step 1. Educator to briefly explain on rates of reaction.</p>

	<p>Step 2. Exposition on mechanism of rates of reaction.</p> <p>Step 3. Discussion on chemical equilibrium.</p> <p>Step 4. Outline factors affecting chemical equilibrium.</p> <p>Step 5. Exposition equilibrium constant</p> <p>Step 6. Learners calculate equilibrium constant.</p>
6	<p>Step 1. Explain basic concepts to learners</p> <p>Step 2. Practical demonstrations done</p> <p>Step 3. Deal with examples from textbooks</p> <p>Step 4. Deal with questions from previous question papers</p> <p>Step 5. Deal with problems from learners</p>
7	<p>Step 1. Demonstration of a reaction illustrating chemical equilibrium</p> <p>Step 2. Develop chalkboard summaries of the demonstration</p>
8	<p>Step 1. Explain concepts involved</p> <p>Step 2. Develop lesson by asking questions to learners</p> <p>Step 3. Let learners do role-play to practically understand the concept</p> <p>Step 4. Answer questions to apply knowledge</p>
9	<p>Step 1. Recap questions</p> <p>Step 2. Use model: balancing scale to illustrate the effect of Le Chatelier's principle</p> <p>Step 3. Group discussion</p> <p>Step 4. Text book reading and make short notes</p> <p>Step 5. Rap up by educator</p>
10	<p>Step 1. Define chemical equilibrium</p> <p>Step 2. Explain factors influencing equilibrium: changing temperature, concentration and pressure.</p> <p>Step 3: calculate K_c.</p>

11	<p>Step 1. Revision of homework</p> <p>Step 2. Link prior knowledge to new knowledge</p> <p>Step 3. Practical examples</p> <p>Step 4. Homework explained</p>
12	<p>Step 1. Balance chemical equations on worksheet</p> <p>Step 2. Demonstration of water steam for reversible reaction</p> <p>Step 3. Demonstration of water and copper sulphate; NO_2 and N_2O_4 reaction on equilibrium</p> <p>Step 4. Calculation of concentration and K_c.</p>
13	Method depends on assumed knowledge.

Figure 1: Summary of Lesson Procedures.

Figure 1 above shows the approaches of 13 of the 40 educators which they usually display in teaching chemical equilibrium in their schools. A few of the educators showed some comprehensive steps that enabled them to cover a good percentage of what the curriculum required about chemical equilibrium. However, majority of the 13 samples proved to make their lessons interactive with and among the learners. Educator 4 above simply noted that *“The educator to explain to learners what is chemical equilibrium. If we add more reactant, then we favour the forward reaction. When we cool up the products, then the backward reaction will be favoured.”* This could explain the shallow level of content knowledge the educator has about chemical equilibrium. Educator 13 appears to believe that *“Method depends on assumed knowledge”*. This educator may have taken method to mean the same as strategy, but it is in error. Strategies are stepwise logical approaches to doing things. Educator 9 saw the concept of chemical equilibrium as just Le Chatelier’s principle and went ahead to show that *“Step 4.”* is

“Text book reading and make short notes”. If this takes place in the class, it could be a mark of unpreparedness for the lesson by the educator.

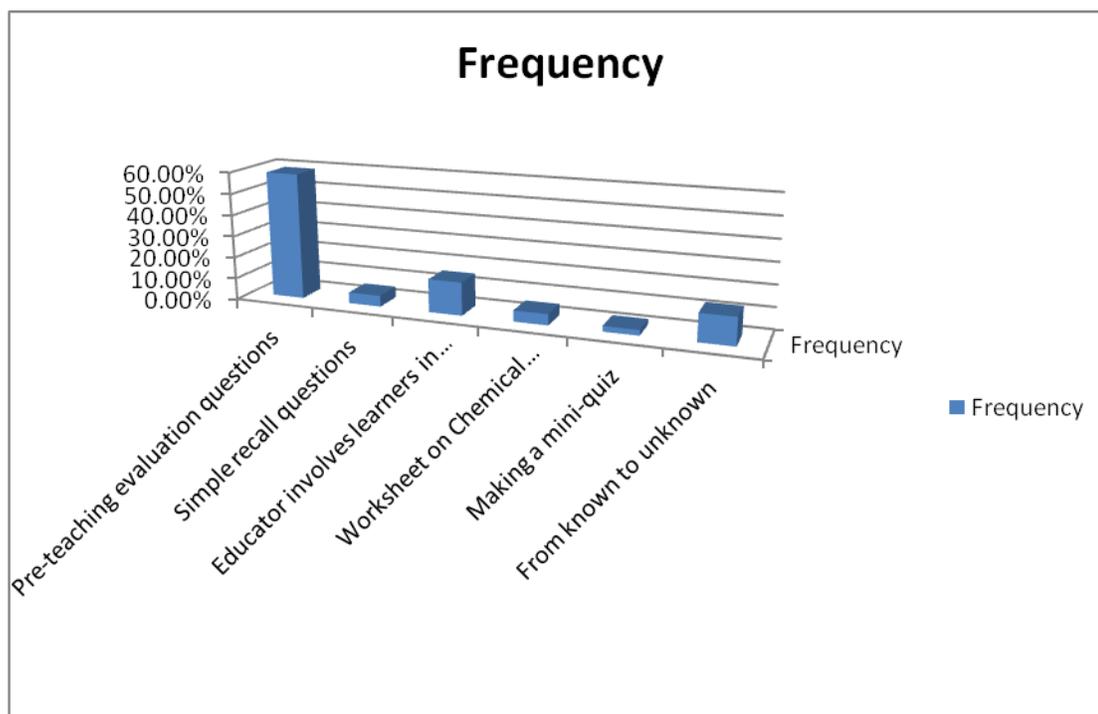


Figure 2: Summary of incorporating learners' prior knowledge

Figure 2 above shows that the educators used different strategies to incorporate learners' prior knowledge in teaching with 58.98% using pre-teaching evaluation questions and 12.82% building from the known to the unknown. Educator involving learners in class discussions accounted for 15.38%. Those using simple recall questions accounted for 5.13%.

Table 12 below shows research results that addressed the first two research questions which are: How are the concepts of chemical equilibrium being taught in schools at FET band? What are

some of the problems when teaching the concepts of chemical equilibrium? The results address the four main experimental parts of chemical equilibrium.

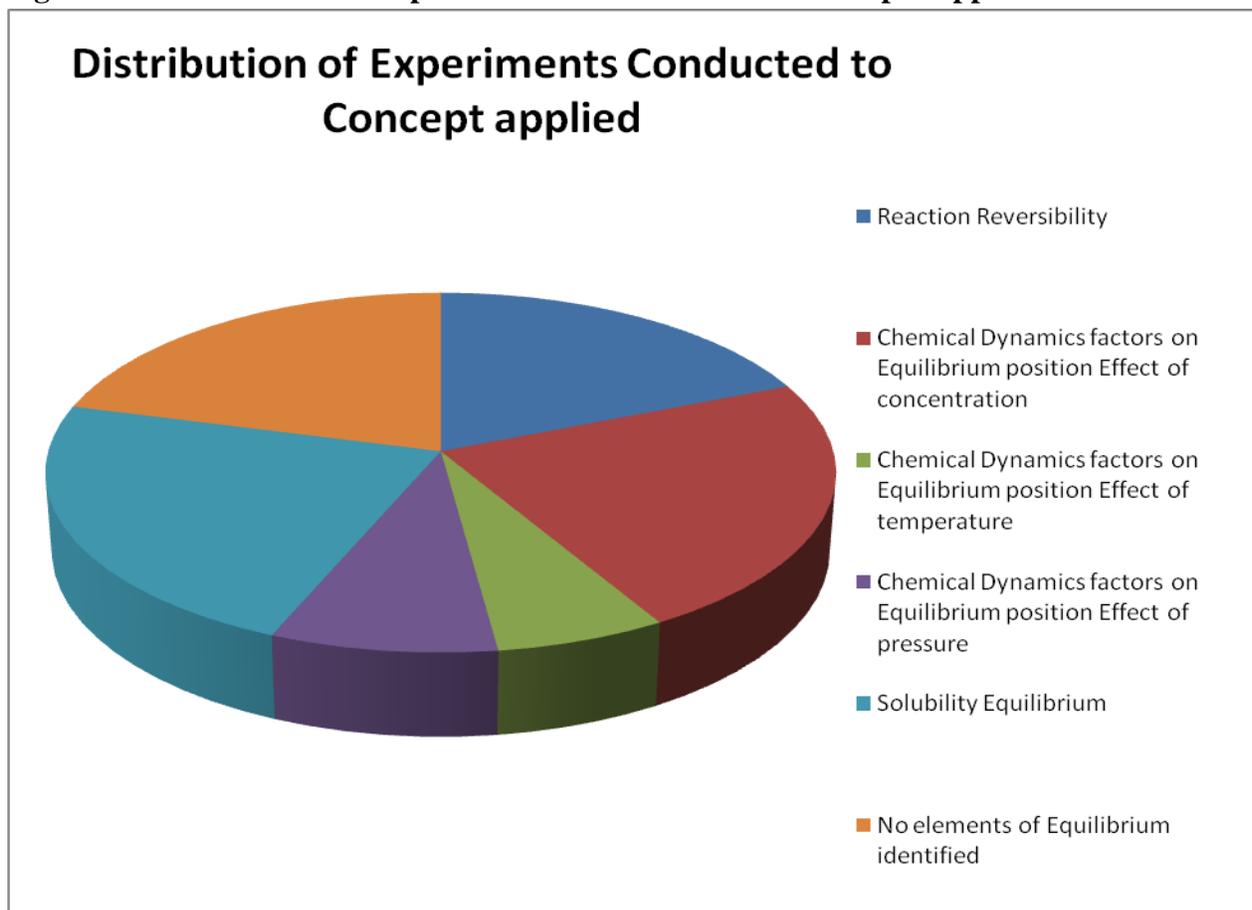
Table 12: Classification of Experiment/ Demonstration to Concept Applied

Concept where applicable		Experiment/Demonstration	Frequency %
Reaction Reversibility		A,B,D,G,	18.75%
Chemical Dynamics factors on Equilibrium position	Effect of concentration	C,H,J,L,M,	22.92%
	Effect of temperature	F,I,	6.28%
	Effect of pressure	E	8.33%
Solubility Equilibrium		K,P,T,U,W,X	22.92%
No elements of Equilibrium identified		N,O,Q,R,S,W,Y	20.83%

KEY: **A:** Reversible reaction for NH_4Cl when heated and cooled. **B:** Elevator Demonstration of reversible Reaction. **C:** Effects of concentration on Chemical Equilibrium CoCl_4 . **D:** Water-steam for reversible reaction. **E:** Effects of pressure $\text{N}_2\text{O}_4(\text{g}) / 2\text{NO}_2$. Observing colour change **F:** Effect of temperature $\text{NO}_2/\text{N}_2\text{O}_4$. **G:** Reversible reaction $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$. **H:** MnO_4^- with OH^- and H^+ . **I:** Place $\text{HNO}_3(\text{conc.})$ in clear, in amber bottle outside in sunlight/ dark.

J: $\text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{S} \rightleftharpoons 2\text{Cr}^{3+} + 3\text{S} + \text{H}_2\text{O}$. **K:** $\text{HCl} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Cl}^-$. **L:** Changes in colour of acid / base indicator. **M:** Acid-base titration. **N:** Burning magnesium in air. **O:** Use a scale balance to explain equilibrium. **P:** Precipitation of Ag^+ with halides. **Q:** Water in container allowed to settle. **R:** Water poured in container until equilibrium is reached. **S:** Disturbing a reaction equilibrium (use of HCl , NaOH , $\text{K}_2\text{Cr}_2\text{O}_7$). **T:** Reaction of Water and Copper Sulphate. **U:** $\text{Na}^+ + \text{Cl}^-$. **V:** $\text{NaCl} + \text{H}_2\text{O}$. **W:** HCl and Zn . **X:** Sugar + H_2O . **Y:** Potassium Permanganate + Glycerine

Figure 3: Classification of Experiment/ Demonstration to Concepts Applied



Experiments or class demonstrations are only conducted for four main concepts on chemical equilibrium which are reversibility of reaction, factors that affect the equilibrium position (concentration, nature of catalyst, temperature and pressure). Effects of concentration were considered highest with a 22.92% followed by reversibility of reaction with 18.75%. Effects of pressure and temperature were put at 8.33% and 6.25% respectively. 22.92% experiments conducted are for solubility equilibrium which are not clear on elements of chemical equilibrium. The remaining 20.83% do not have elements of chemical equilibrium. 43.75% do not contribute significantly to the teaching concept of the chemical equilibrium.

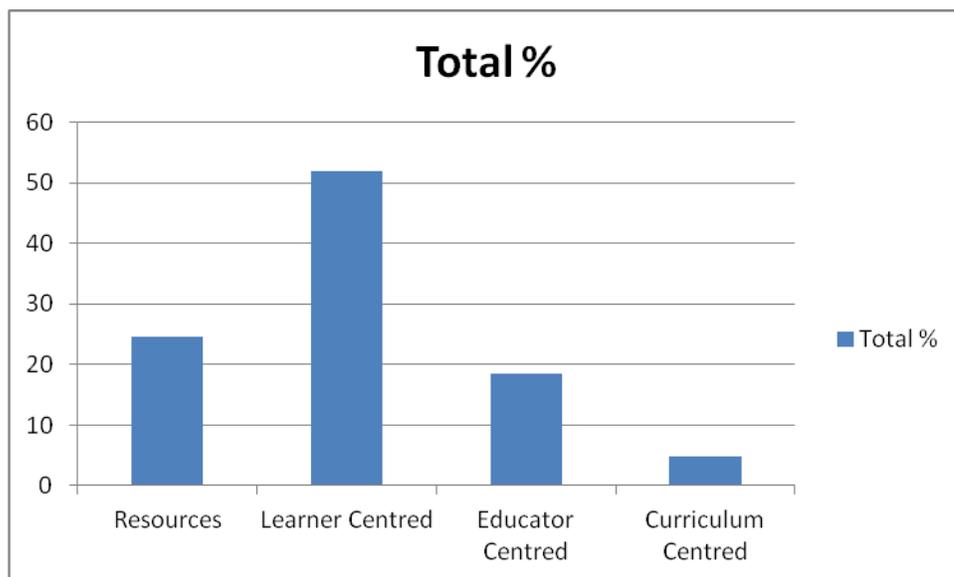
Table 13 of the research results addressed the research question on problems of teaching the concepts of Chemical Equilibrium.

Table 13: Categories of Problems/ Challenges when teaching Chemical Equilibrium

Category	Variables	Total %
Resources	B,G,R	24.7%
Learner Centred	C,D,E,H,I,J,L,N,P,S	51.9%
Educator Centred	F,K,M,Q,R	18.5%
Curriculum Centred	A,M	4.9%

KEY: **A:** Le Chatelier's principle need to be demonstrated/experimented to see effect. **B:** No apparatus, therefore it is difficult to teach concept. **C:** Learners have problems in Maths, problems in doing calculations. **D:** Learners unable to apply Le Chatelier's principle. **E:** Most learners have a haze understanding of English. **F:** Educator following steps up to the end of a K_c problem. **G:** Lack of text books. **H:** Drug abuse. **I:** Ill discipline and lack of commitment of learners. **J:** Most learners can't write simple equations and balancing them. **K:** To come up with practical examples on this section which learners will be able to observe and imagine. **L:** Learners visualises equilibrium as static. **M:** Most reactions are not followed by observable changes as colour and temperature. **N:** Lack of background and basic concepts of chemical reactions and energetic. **P:** Learners' prior knowledge of equilibrium. **Q:** Teaching concepts as separate entities. **R:** Poor teaching and learning support materials. **S:** Lack of logical thinking by learners

Figure 4: Categories of Problems/ Challenges when teaching Chemical Equilibrium



All the problems are classified into four categories through factor analysis as have been shown in Table 13 and Figure 4. The learner centred category accounted for 51.9%. These are problems directly related to learners. The resources category which range from lack of laboratory apparatus, text books and poor teaching materials accounted for 24.7%, followed by the educator centred problems as 18.5%. The educator centred problems can be deficiency in content knowledge or pedagogical knowledge skills. The curriculum centred problems are at 4.9% and these include the need to demonstrate Le Chatelier's Principle and the suggested reactions not showing observable changes as colour and temperature. There is overlapping of variables within the categories, meaning they are inclusive.

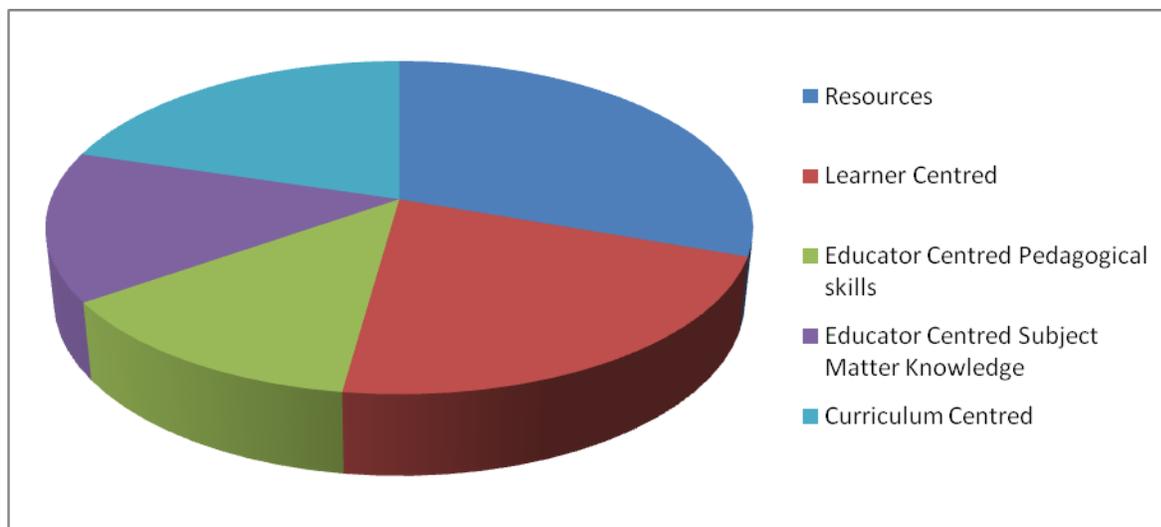
Table 14 and Figure 5 address the research question on causes/sources of the problems of teaching the concepts of chemical equilibrium at the FET band.

Table 14: Categories of Sources of Problems

Category		Source of problem	Frequency %	
Resources		A, B, I, J, M	30.43%	
Learner Centred		C, D, L, N	21.74%	
Educator Centred	Pedagogical skills	E, H, M	13.04%	27.53%
	Subject Matter Knowledge	K, M	14.49%	
Curriculum Centred		F, G, N, K	20.29%	

KEY: **A:** Lack of financial resources. **B:** Lack of laboratories/ apparatus chemicals. **C:** Ill discipline of learners. **D:** Lack of commitment on school work from learners. **E:** Teaching techniques lagging behind technological development. **F:** Too much group work at primary level leading to inadequate numeracy and literacy skills. **G:** Flawed design of the syllabus. **H:** Improper teaching. **I:** Lack of qualified science educators at GET and primary schools. **J:** Lack of suitable textbooks. **K:** Concept too abstract. **L:** Failure by learners to carry out simple calculations without using a calculator. **M:** Under qualification of educators teaching Physical Sciences. **N:** Large number of learners progressing to the next grades without passing science.

Figure 5: Categories of Sources of Problems



In order to simplify and have a more comprehensive analysis and interpretation of sources of problems, all variables are classified into four categories which are resources, learner centred, educator centred and curriculum centred sources of problems/ challenges. On resources this includes text books, laboratory equipment and financial resources. Resources have the highest percentage of 30.43% as a source of problem facing the teaching and learning of Chemical equilibrium. Learner-centred sources of problems account for 21.74% with the two categories of educator-centred sources of problems at 27.53%. On the educator centred, the pedagogical centred problems made up 13.04% and the subject content knowledge was 14.49%. Curriculum centred sources which stretch from syllabus design to proposed and promoted learning strategies, and the promotion of learners to the next grade accounted for 20.29%.

Table 15 addresses the research question on perceived effects of problems of teaching concepts of chemical equilibrium on learners' performance.

Table 15: Categories of Perceived Effects on Learners' Performance

Category	Variables	Frequency %
Learners fail Examinations	A, B, D, J	56.86%
Learners fail to make sense of Chemistry	C, E, F, G, H, I	43.14%

KEY: **A:** Impact negatively. **B:** Poor performance. **C:** Learners cram taught concepts and fails to apply these concepts in higher order questions. **D:** Learners will not make it at the end of the year. **E:** Poor application of concepts when answering questions. **F:** Negative attitude. **G:** Failure by learners to comprehend the reality of chemical concepts, hence chemistry remains to be farfetched ideas. **H:** Problems in answering questions as it is too abstract. **I:** Reduced performance due to poor communication with question paper. **J:** Learners fail to solve mathematical problems.

The perceived effects of problems on learners' performance are two categories which are closely linked to each other. 56.86% of the respondents believed that learners generally and normally fail their final Grade 12 examinations at the end of the year irrespective of way they are taught. The remaining 43.14% believe learners fail to make sense from chemistry lessons and will not have any future of it. This implies that even the educators see Physical Science to be difficult and incomprehensible to the learners.

Research results presented on Tables 16, 18 and 19 addresses the research question on prospects of teaching concepts of chemical equilibrium at the FET band.

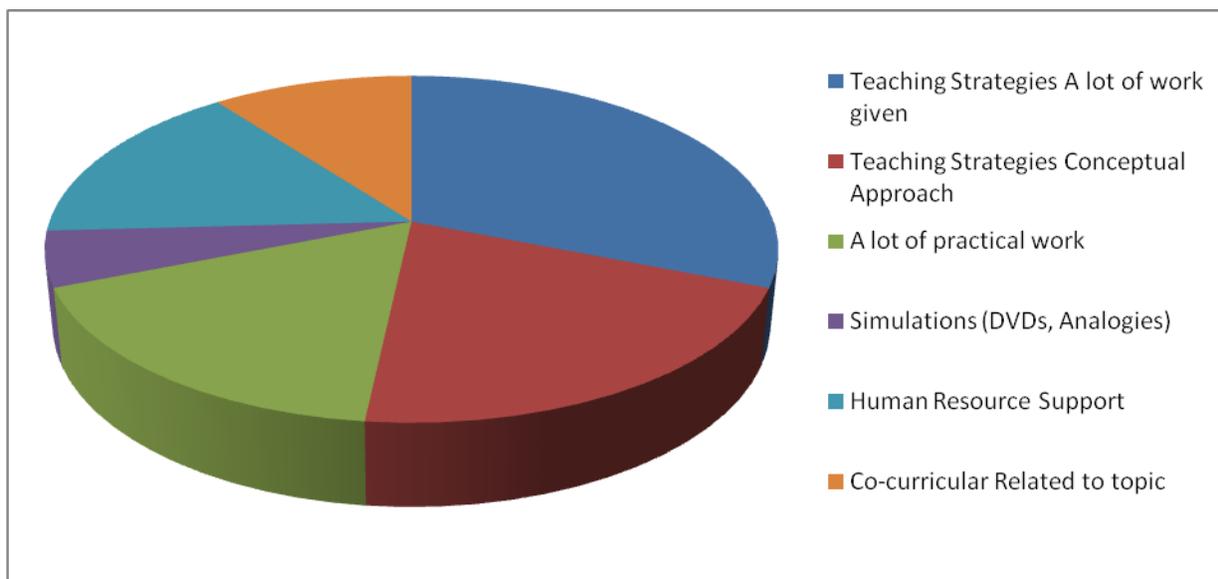
Table 16: Categories of Possible Solutions/ Prospects of Teaching Chemical Equilibrium

Category		Variables	Frequency Percentage	
Teaching Strategies	A lot of work given	E, F, P	31.03%	51.72%
	Conceptual Approach	H, L, M, N, T, U, V	20.69%	
A lot of practical work		B, G, J, R,	17.24%	
Simulations (DVDs, Analogies)		C,I	5.17%	
Human Resource Support		K, S, W	15.51%	
Co-curricular Related to topic		A, D, O	10.34%	

KEY: **A:** Visiting science centres. **B:** Improvise. **C:** Think of analogies. **D:** Educational tours. **E:** Giving learners remedial work. **F:** Giving learners more work and expose them to many questions using past examination questions. **G:** Teacher demonstrates experiment. **H:** Topic must be given enough time to be taught thoroughly and effectively. **I:** Use DVD/ Video simulations. **J:** Give learners a lot of practically related questions. **K:** Invite experts to treat the concepts. **L:** Identify barriers which learners have such that topic is treated like any other topic. **M:** Make learners work in groups. **N:** Learners must understand it and able to apply it in real life. **O:** Learners need educational tours on this topic to value its importance to them.

P: More problems and practice should be given to learners. **Q:** Prospects are bright. **R:** Remain uncertain as long as support in terms of apparatus of laboratory are lacking. **S:** Expect more learner and parents' involvement. **T:** Relate concepts with other concepts and subjects. **U:** Teach it continuously. **V:** Some concepts should be introduced at lower levels. **W:** Empowered educators may bring learners' confidence

Figure 6: Categories of Possible Solutions/ Prospects of Teaching Chemical Equilibrium



The possible solutions to the identified problems form part of the prospects on the teaching of the concepts of chemical equilibrium are shown in Table 16 above. Variables in the key to Table 16 and figure 6 are classified into five categories as Teaching Strategies, A lot of practical work, simulations (DVDs, Analogies), human resource support, and co-curricular related to topic. Improving teaching strategies showed the highest percentage of 51.72% and this is sub-divided into those who advocate for a lot of work given to the learners (31.03%) and those who advocate for strategy that promote conceptual change (20.69). A significant number of the educators (17.24%) advocate for a lot of practical work since physical science is considered a practical subject. Human resource support to both educators and learners with a lot of parental

involvement stands at 15.51%. Co-curricular activities related to the topic accounted for 10.34% with the use of simulations as 5.17%.

Table 17: Support on Teaching Chemical Equilibrium

Yes, Support Given	No Support Given
17.5%	82.5%

Table 17 shows that only 17.5% of educators have been given some forms of support through workshops on the teaching of chemical equilibrium. 82.5% of the respondents never received any support whatsoever to be able to effectively teach chemical equilibrium. The implication of this observation is that giving adequate and appropriate support to physical sciences educators forms a very promising prospect for the teaching of chemical equilibrium.

Figure 7: Categories of Innovations

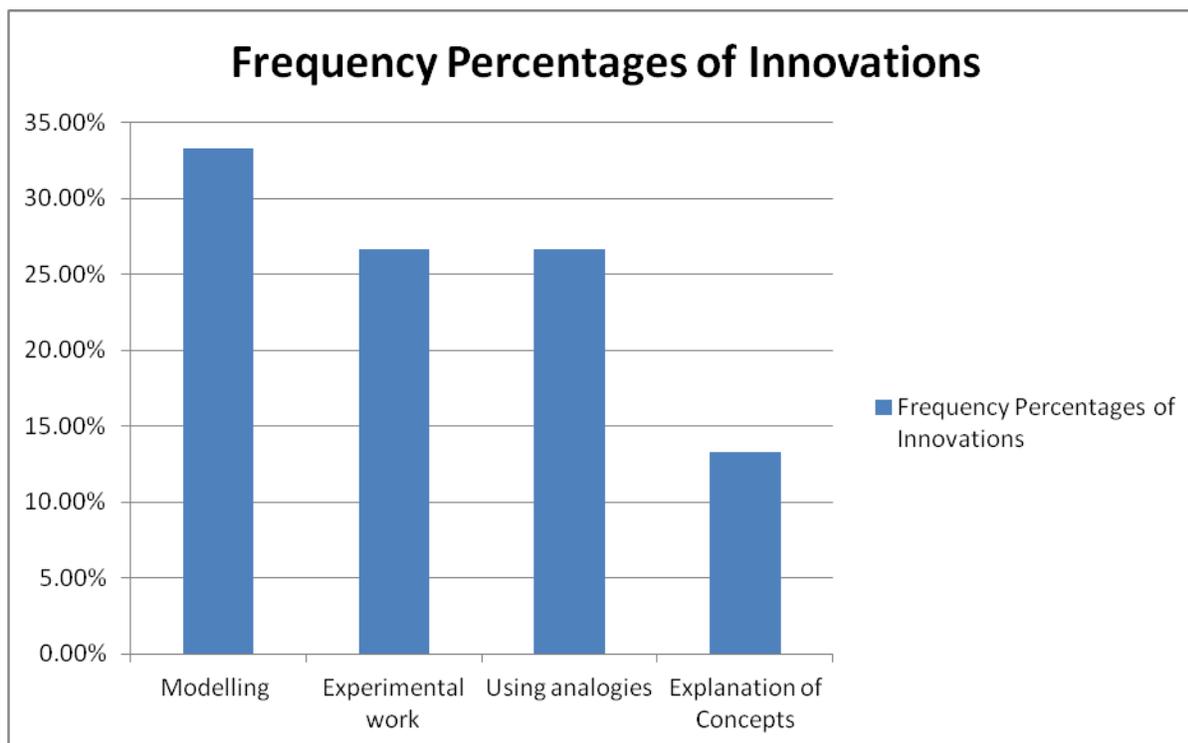


Table 18 research results address the research question on how the concepts of chemical equilibrium are being taught in schools at FET band.

Table 18: Categories of Innovations when teaching Chemical Equilibrium

Category	Variables	Frequency %
Modelling	E, F, I	33.33%
Experimental work	A, C, G	26.67%
Using analogies	J, D, K	26.67%
Explanation of Concepts	B, H	13.33%

KEY: **A.** Practically demonstrates reversible reactions. **B.** Kc concept and questions categorised and taught separately in stages of difficulty. **C.** Doing many experiments. **D.** Analogies to explain equilibrium e.g. soccer game substituted players. **E.** Modelling to explain concepts. **F.** Use more media such as videos, newspapers, posters, and internet. **G.** Improvisation of apparatus. **H.** Explain how some factors like catalyst, temperature functions. **I.** Game playing. **J.** Contextualise the concept. **K.** Use analogy of escalator.

Figure 7 and Table 18 above show that `Explanation of concepts` is rated the least innovation by 13.33% of respondents suggesting that the use of it is still fundamentally important. However, modeling (33.33%) has been seen as the most plausible innovative way followed by experimental works (26.6%) and the use of analogies (26.6%) to improve the teaching of chemical equilibrium..

Figure 8: Ways of Improving Quality of Teaching

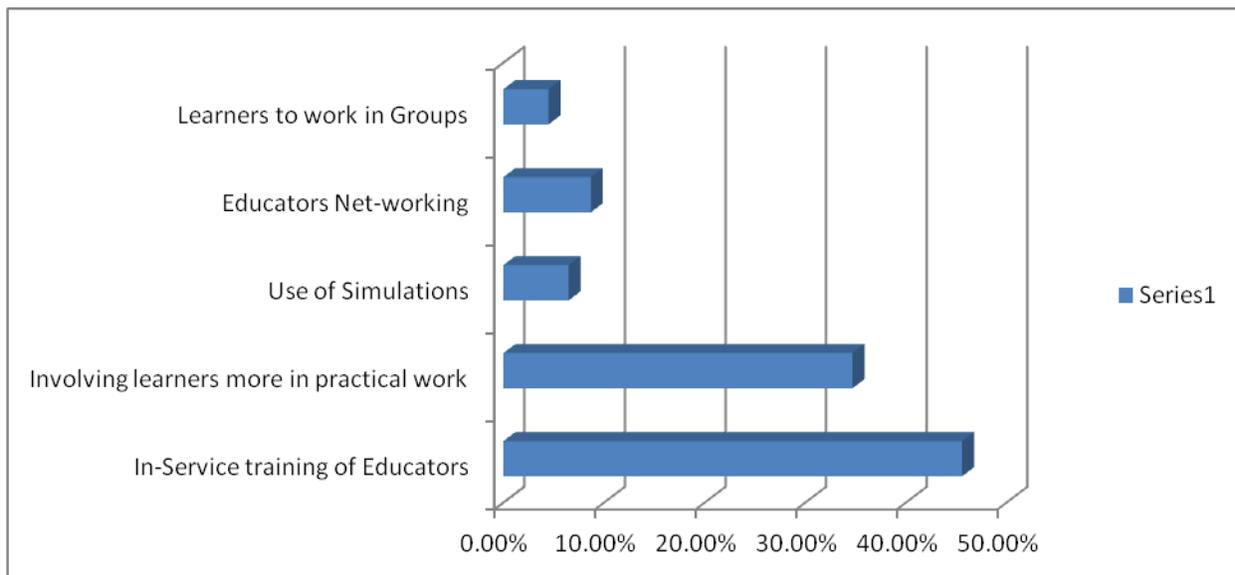


Table 19: Categories of Ways of Improving the Quality of Teaching

Category	Variables	Frequency
In-Service training of Educators	A,B,C,J	45.6%
Involving learners more in practical work	E,G,H,I	34.7%
Use of Simulations	K,L	6.5%
Educators Net-working	F	8.7%
Learners to work in Groups	D	4.5%

KEY: **A:** Workshops are needed to empower educators. **B:** Educators be given bursaries to further their education. **C:** Re-train educators on how to teach specific topics. **D:** Encourage learners to work together in a team/ group so that they can learn more effectively. **E:** Making teaching as more practical as possible. **F:** Educators should share information on problems faced helping each other. **G:** Provide laboratories and chemicals. **H:** Learner involvement and practical work emphasized. **I:** Learners should be given the opportunity to do experiments own their own. **J:** Upgrading educators with new teaching strategies. **K:** Using more simulations. **L:** Contextualise the concepts to real social life.

Figure 8 and Table 19 indicate that 45.6% of the educators suggested that the quality of teaching can be improved through In-Service Training of educators, followed by 34.7% of them advocating for actual involvement of learners in more practical works. The use of simulations was upheld by 6.5% of the educators as a way forward for effective teaching of chemical equilibrium and those in support of educators net-working with others accounted for 8.7% while the remaining 4.5% supported learners working in groups. The general information on the teaching of chemical equilibrium provided by the respondents was on the need to have good textbooks which address all concepts as required by the syllabus. Educators suggested that teaching should be in line with technological development and that learners should be provided the opportunities to access the internet for additional information. The practical application for chemical equilibrium principle should be emphasised by the educators.

Chapter 5

Findings and Discussions

Research findings of this study are discussed under two major sub-headings: Categories of problems facing the teaching of chemical equilibrium and the prospects of teaching chemical equilibrium. Such problem areas as have been analysed and identified as environmental problems, resources and sources of information, educators' subject matter knowledge, methodological or pedagogical problems, learner centred problems, and miscellaneous problems have been fully discussed under the categories of problems. Possible intervention strategies are also indicated as part of the prospects of teaching chemical equilibrium.

5.1 Categories of Problems facing the teaching of Chemical Equilibrium

All problems identified are put under the following sub-headings: Environmental, resources and sources of information, educator's subject matter knowledge, methodological or pedagogical and learner centred problems among others.

5.1.1 Environmental Problems

The South African policy on education recommends a ratio of one educator for every 30 learners at the FET band. The physical science educator- learner ratio is unbelievably 1:328 based on the data collected for this study. This is about eleven times above the expected norm. This is the case where only one or two qualified physical sciences (chemistry) educator(s) is/are found in a whole school. This condition will always impact negatively on the quality of teaching as the desired skills and knowledge to be acquired will be difficult to achieve with too many learners under the care of an individual physical sciences educator. It becomes more challenging for the educator to

attend to all learners effectively. The average number of learners per class being 51 is almost double what obtains in Sub-Saharan Africa which is 25.8 while the world's recommendation stands at 18.0 (UNESCO Institute for Statistics, Data Centre, 2008). This shows that the classes are overcrowded. Teaching large classes require special skills from the educators otherwise they end up employing teaching strategies which are suitable for the environment but may not suit the learning characteristics of the learners.

The availability of a science laboratory at a school provides a conducive environment for the teaching and learning of physical sciences because Learning Outcome 1 (LO) of NCS is scientific inquiry and problem-solving skills where learners are expected to conduct practical investigations (Department of Education, 2003). It becomes very difficult if not impossible to conduct the practical investigations, when there is no equipped laboratory. The concepts of chemical equilibrium are abstract and they need to be demonstrated or experimented upon under educators' supervision to give the learners the required skills and comprehension. Due to lack of laboratories and apparatus educators end up using conventional methods of teaching, making it more difficult to create imaginary pictures in learners' minds about the concepts of chemical equilibrium. The schools with laboratories still face some challenges because the educators only do class demonstrations and the learners are not given the opportunity to investigate for themselves due to the large number of learners in the class at a time.

5.1.2 Resources and Sources of Information

Physical Science teaching is expected to promote the use of process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts (Kelder, Govender and Govender, 2007). It

also emphasizes investigations by learners to discover for themselves the natural laws, and reconsider, restructure their conceptions and alternative ideas while focusing on personal and social and economic development (Vamvakeros, Pavlatou and Spyrelis, 2010). Research results of this study show that there is minimum attempt by educators to focus and design their teaching in a way which can promote what is expected in the present day chemistry teaching. The sourcing of information from different sources remains a challenge as this study's results show that the main sources of information for educators are the very same text books which are used by learners.

The results showed that a few text books get consulted by the educators, many of the educators are not satisfied with contents presentations of the text book and all these underpin the need to consult many text books for wider gains of consultation. However, this is not done since an average of 2 text books are consulted by each educator and the educators fail to provide enough information to learners. As a result, the educators become less confident in teaching the topics. This may be one reason to advocate for empowerment through re-training and workshoping on the topic contents and to be equipped with new pedagogical skills. Kriek & Grayson (2009) proposed a holistic professional development for physical science educators while they indicated that improvement for educators' content knowledge increases educators' confidence, which in turn, makes them more prepared to use a variety of teaching strategies that are learner-centred and activity based. The educators feel that the only support from curriculum advisors (CA) is not enough with the huge challenges they encounter in teaching the topic although on paper they indicated that they are confident in teaching the basic concepts of Chemical Equilibrium.

Teaching according to the educators is text book based with minimum additional source of information. The educators' total dependence on textbooks being used shows that their ultimate

goal is just to make the learners pass NSC Examinations regardless of skills acquired. This is supported by Chiappetta, Sethna, and Fillman (1991) saying, “textbooks carry large volume of information which learners memorize and reproduce during examinations. These textbooks mention ideas without developing around the models that scientists used to form these concepts.” The situation is made more complex by not having any of the prescribed textbooks for the syllabus that covers all relevant aspects of the topic chemical equilibrium. An average of 2 textbooks being used by educators when teaching the concept of chemical equilibrium is too limited to the activities in the few textbooks and past examination papers. This shows minimum effort from educators to outsource information, limiting the study of chemical equilibrium to a few textbooks and this gives a wrong impression to the learners on the learning and meaning of physical science.

Some of the educators make effort in using class experiments or experimental demonstration when teaching the concepts, but this is hampered by lack of laboratories or laboratory equipment to do the experiments Table 4a, 4b and Table12). A few of the schools are using whatever resources available to make the learners do the experiments for example: *T1, “..... we have improvised, no real laboratory, we are using the former Home Economics room as a science laboratory.....”* This is made to simplify the educators’ role when teaching the practical aspect where the learners are supposed to plan, design and conduct practical investigations and experiments, although practical investigations given to learners are only those for formal assessment, not for developing skills as this study found out.

Contextualising the concept of chemical equilibrium remains farfetched and a difficult task to the learners the moment learners fail to see and relate such to their daily lives. Lack of material resources leads the educators to employing strategies which do not suite the learning

characteristics of learners and not appropriate for the development of particular concepts to promote science skills development but only cover the content for the purpose of syllabus coverage and only make learners pass end of year final examination if they are able.

5.1.3 Educators' Topic Content Knowledge

Topic content knowledge remains a key issue to the teaching of a particular concept like chemical equilibrium. Topic content breadth is only mastered after an educator has taught the topic (Mulhall, Berry and Loughran, 2003) despite having covered the content at a higher level of study like the University. The correlations coefficients for the educators' confidence in teaching the basic concepts of chemical equilibrium which are reaction incompleteness, reaction reversibility, chemical dynamics and equilibrium constant are strongly statistically significant. This overconfidence by educators is having a negative effect on their teaching. These negative effects are demonstrated by the statistically non-significant correlation between preparation time and textbooks used by the educators and also between textbook used by educators and textbooks satisfaction, because these correlations are expected to be closely associated if educators do not work with the assumption that we know everything. The basic concepts are closely related in such a way that if an educator has a problem on one of them, the problem will have an effect on the other concepts.

Overconfidence, lack of adequate preparation, lack of adequate resources, lack of in-service training have resulted in educators demonstrating unprecedented problems on the content knowledge of the concepts of chemical equilibrium. For example some of the educators tried to explain equilibrium using *“the tug of war or filling a cup with water and say equilibrium is reached”*.

Responses from educators show that there is a problem in explaining the incompleteness of a reversible reaction. For example, T1 “..... *the incompleteness of a reversible reaction can be due to factors which affect rate of reaction for example little concentration can lead to incompleteness of reaction but if we put more concentration of the reactant, then we can have some completeness*”. To the particular educator, concentration is what determines whether the reaction should get to completion or not. The educator refers to a reversible reaction being complete yet there is continuous movement of particles at microscopic level even when at macroscopic level there seems to be nothing happening when the reaction has reached chemical equilibrium.

The basic concepts of chemical equilibrium have proved to be a problem to the educators although a high percentage of them feel very comfortable and comfortable in teaching them by their responses. Educators struggle to link the key concepts and the basic principles when explaining the basic concepts. T₃ on reversibility says, “..... *dynamic Equilibrium means the forward and reverse reaction are equal therefore that is why it is reversible. It means the reverse reaction will go in the forward direction and there after it could reverse again*”

Alternative conceptions were found in T₃, as part of the sources of alternative conceptions in learners. According to Kelder, Govender, and Govender, (2007), “dynamic equilibrium is when the rate of the forward reaction equals the rate of the backward reaction” (p 286).

Misconceptions of learners on chemical equilibrium mentioned by Quilez (2007) quoted in Van Driel and Gaber (2002) for example: believing the forward reaction goes to completion before the reverse reaction commences; misrepresent the changes that occur in chemical equilibrium when conditions are altered; unable to distinguish between rate (how fast) and extent (how far) a reaction goes and others are clearly manifested in many educators’ content knowledge. With the

educators using conventional or traditional methods of teaching like exposition when explaining concepts, these misconceptions are transferred directly to the learners, with the educator being the source of alternative conceptions.

5.1.4 Methodological or Pedagogical Problems

Topic pedagogical knowledge is acquired only after an educator has taught the topic (Mulhall, Berry and Loughran, 2003). Some educators focus on examination questions rather than syllabus content matter as prescribed in the curriculum. Curriculum interpretation is based more on examination results than focus on science process skills development and making science more meaningful through active teaching strategies. This is expressed by educators who only give tasks to cover examination questions, including requests for textbooks which focus on examination questions and techniques. There is a shift in teaching from making science more meaningful to academic results oriented instruction. Outcome Based Education become more of Result Based Education and added to ugly scenario.

On the basic concepts of chemical equilibrium some educators are not sure of what comes first between dynamic equilibrium and reversibility of reaction. T_1 and T_2 believed that there must be dynamic equilibrium to achieve reversibility of a reaction. In this regard it becomes more complex for the learner to have a scientific comprehension of the concept.

There is rapid development in scientific technology with everything almost being computerised. One major problem identified is the lagging behind of teaching techniques compared to technological development. Though not tested in this study, anecdotal evidence suggests that learners become less motivated and might not explore more as they might do when using latest technological equipment. Computer simulation might be used especially by those schools with

more financial, material and human resources. Educators themselves are not using the latest technology as a source for special activities and reference purpose.

Poor building block of basic scientific concepts at the General Education and Training (GET) band that are later applied at the FET is one of the major problems identified by educators and curriculum advisors (CA). CA₁ described the situation in a more concise way by saying, “.....*due to shortage of Physical Science educators, more qualified and 'better performing' educators in schools are deployed to teach the FET band leaving the GET band with under qualified educators, some with very little knowledge of science. These educators end up teaching mainly the Biology and Geography part of Natural Science leaving the Chemistry and the Physics sections. In some cases when they are taught the educator reads the textbook to the learner instructing them to copy some aspects as notes.*” What the CAs were saying shows that the problem of learners does not start at the FET but at the GET band such that some problems come as a result of knowledge gap between what the learners are expected to know and what they know. Concepts taught at the FET band seem so abstract because learners do not have a strong scientific background. The CAs recommended the redeployment of educators to balance the gap of quantity and quality of educators between the GET and FET bands.

5.1.5 Learner Centred Problems

Considering the problems of teaching chemical equilibrium identified by educators, 51.9% are learner centred. These learner centred problems include both attitude and aptitude. Most of the learners have a hazy understanding of English language which is used as a medium of instruction. English to the learners is the second or third language. This was confirmed by Vonk, De Feitter, and Akker, (1995) and Van den Akker (1995) on summarising researches conducted

in Southern Africa including South Africa, Botswana, Namibia, Lesotho and Swaziland. The hazy understanding of English leads to communication breakdown between the educator and the learner and also between the learner and the Chemistry subject. Chemistry language is of a more advanced stage of English language since learners translate English and sometimes Latin statements into chemical symbols and chemical equations. The communication breakdown demotivates the learners and this de-motivation starts at lower grades, as a result knowledge gaps emerge. Learners still progress to the next grade with wide knowledge gaps and without passing science, as indicated by the educators. The teaching of concepts of chemical equilibrium becomes a challenge because the learners will be having knowledge gaps on the basic concepts of chemistry which should have been used as back-ground for improved comprehension of the concepts.

Also learners have a problem of carrying out simple calculations in Mathematics as indicated in this study, whose results agree with what Scharberg, (2005) found. The learners pluck in numbers in a given formula and punch in the figures in the calculator. Due to a limitation in English language and mathematical skills, learners do have problems in conceptual understanding and as a result when solving problems they use the algorithm method (Bodner, 2003; Toth and Sebesyten, 2009). At the end they are unable to explain the significance or scientific meaning of the answers they get. The educator's tasks of facilitating the learning process become more challenging as he has to see to that the knowledge gaps in learners are reduced or narrowed down.

The communication breakdown may be reduced by making learners visualising the phenomenon of the concepts of chemical equilibrium. Unfortunately, it is not all schools that have laboratory equipment and facilities for physical science (see Table on Laboratory and Apparatus

availability). Precaution should be taken especially on experimental demonstrations conducted on the concepts of chemical equilibrium as the research results show some experiments being conducted complicate the concepts being demonstrated because elements of equilibrium are not clear.

Psychologically, there is a strong relationship between aptitude and attitude. The communication breakdown between learners and chemistry language leads to frustration on the part of the learner leading to ill discipline, lack of interest and commitment in the subject. These were pointed out as part of learner problems. When this happens, it becomes difficult for the educator to teach the learners and achieve the intended objectives.

5.1.6 Miscellaneous Problems

The results on lesson procedures show a variety of ways of approaching the concepts of chemical equilibrium. The results are similar to those of previous researchers (Vonk, De Feiter and Van Der Akker, 1995; Gobert and Buckley, 2000; Laburu and Niaz, 2002; Bodner and Herron, 2003; Mayer, 2004; Cardellini, 2006) which vary from traditional instructional method to active instructional methods with different educators' PCK level demonstrated. Previous researches for example Quilez (2003); Gussarsky and Gorodetsky, (1990); Chiu, Chou, and Liu, (2002) showed that learners have conflicting ideas on key terms of equilibrium like system, shift, constant, state of balance, equilibrium and many others with the textbooks used also not explaining these terms but only applying them. None of the procedures indicated by educators showed some ways of trying to address the terms. This was further stressed during the interviews as the educators failed to give any clear guide on how to address the basic terms but only applied them.

Discussing educators' topic content knowledge and pedagogical knowledge level in relation to learners' conceptions, Mulhall, Berry, and Loughran, (2003) and Bucat, (2004) opined that at the beginning of the topic, learners may be given key terms to define like system, shift, constant, state of balance, and equilibrium. After giving learners adequate time to respond in writing, the educator instructs learners to revisit their definition/explanations as they progress on topic coverage. This approach may assist learners as they compare their conceptions and scientific conceptions when they look at the applicability of the concept to the context in the topic.

In terms of Age of educators, 21 of them were between 41 – 45 years, and 30 educators above the age of 36 showed a low level of innovations. The teaching experience is not translated into improved strategies of teaching as shown by the sample of lesson procedure (Figure 1). Only seven (17.5%) of the 40 respondents received support in the form of workshop on teaching the concept of chemical equilibrium to make them more qualified educators. The lack of In-Service training to educators is a problem since educators are supposed to go through a professional cycle (Steffy's model, 1989) of entry stage, expert master, renewal stage and withdrawal stage. Some educators may have passed the renewal and withdrawal stages and if no professional development is carried out at renewal stage they end up at the exit stage. At the renewal stage educators need re-training and work-shopping on subject matter, new teaching strategies and changes in the curriculum to keep them abreast with any changes.

5.2 PROSPECTS

There is a strong relationship between ways of improving the quality of teaching and possible solutions of problems of teaching chemical equilibrium and prospects of teaching chemical equilibrium. The main focus of the educators should be on improved teaching strategies, how

learners can be given a lot of work and using strategies that promote conceptual understanding. Educators do not have the necessary skills to implement the strategies which promote conceptual change and understanding as a result they advocate for In-Service training on teaching strategies for the particular topic. Up-grading of educators in terms of topic content knowledge in order to gain confidence in teaching the topic is highly advocated by the respondents. Some of the more ‘experienced educators who produce good results’ at the NSC examinations strongly suggested a form of uniformity on how educators teach a particular topic (T₁ and T₂). According to them, this is to narrow down the performance gap between from learners from different schools during the national examinations.

The ability of teaching of basic concepts to revolve around rates of reaction (T₁, T₂ and T₃) will enable the learners comprehend, be able to explain and apply rates of reaction. This is considered as prior knowledge for the successful teaching of the concepts. Reference to rates of reaction should always form when teaching chemical equilibrium. Most of the learners’ textbooks (Jones, Davies, and Mgoqi, 2007; Kelder, Govender, and Govender, 2007; Kelder, Govender, and Govender, 2007) use the following statement to represent a chemical reaction:



They deduce the K_c as follows:

$$K_c = [C]^c [D]^d / [A]^a [B]^b$$

The learners usually fail to deduce the K_c expression for particular reactions but simply retain the example as the K_c expression. T₁ referred to A, B, C and D as *variables which only represent reactants and products which depend on each particular reaction*. Several examples of chemical reactions are given to learners to come up with K_c expression applying the variables. No learner

textbook referred to these as variables but this is a significant contribution to the solution of the problem.

The result of this study shows some amount of confusion among educators about problem-solving and solving-problems as a teaching strategy. Educators are to use problem-solving strategy as an effective strategy that involve active learning and promote conceptual understanding in learners. They give learners a lot of 'problems' to solve and take this as problem-solving strategy. Previous researchers in Cardellini (2006) agree with this statement. Cardellini (2006) said problem-solving is a process in which various reasoning patterns are combined, refined, extended and invented. Since educators prefer this strategy In-Service training to develop skills on how to implement the problem-solving strategy when teaching chemical equilibrium basing on previous research findings (Mayer, 1975; Johnstone and El-Banna 1986; Niaz, 1987; Tsaparlis et. al, 1987; Cardellini, 2006; Wood, 2006). Although there are different ways in which researchers define problem solving, the Wheatley method of problem solving in Bodner (2003) is recommended and adapted. Approaches used by educators to teach the topic which are question and answer, group discussions, discovery and 'problem-solving' can all be aligned and developed into one strategy which is problem-solving through up-grading of educators' skills.

Involving learners in practical work using the problem-solving strategy is regarded by many of the educators (34.7%) as a possible solution or prospect to the teaching of the topic chemical equilibrium, and 26.67% on innovations, a as ways of improving the quality of teaching. With 20.83% experiments/ demonstration done without showing major elements of demonstrating concepts of chemical equilibrium, the number of experiments conducted by each educator is very low. This has always had a negative consequence on the learners` performance in Physical

Science (Chemistry) in the examinations. Through In-Service Training, educators are expected to be trained and retrained on basic experiments to be conducted during the teaching of particular concepts of chemical equilibrium. POE is a more positive approach in applying experimental work (Chiu, Chou, and Liu, 2002) especially when using experiment activities that are ‘simple and clearly show elements’ of chemical equilibrium. POE when implemented ‘correctly’ is an active teaching strategy which promote conceptual change and understanding because learners are able to compare what they already think about, and express their conceptual framework for the phenomenon with what they observe.

Experiments / demonstrations of basic concepts of chemical equilibrium needed to be identified and should form part of the In-Service training of educators on how to conduct the experiments and the pedagogical aspects to be included (Bond-Robinson, 2005). The following are the basic concepts and the experiments selected and recommended for each concept:

1. Reaction Reversibility

- Boiling water in a closed container
- Warming NH_4Cl in a closed test tube and use wet red and blue litmus paper
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

2. Reaction Incompleteness

- Boiling water in a closed container
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

Chemical Dynamics factors:

3. Effect of concentration on Chemical Equilibrium position

- $\text{Cr}_2\text{O}_7 / \text{CrO}_4^{2-}$
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

4. Effect of temperature on Chemical Equilibrium position

- $\text{NO}_2 / \text{N}_2\text{O}_4$
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

5. Effect of pressure on Chemical Equilibrium position

- $\text{NO}_2 / \text{N}_2\text{O}_4$

The reactions indicated above may be used to simplify the switching of learners from the macroscopic level of thinking to microscopic and then to representational level or from macroscopic to representational then to microscopic level (Johnstone, 2000).

The inability of learners to apply the concepts of equilibrium shows that the strategies being used are not promoting conceptual understanding in learners. A lot of practical work has been advocated to reduce the communication breakdown between learners and subject language. However, this is always faced with the problem of gross shortage of laboratory material/apparatus in many of the schools. In the face of such problems, analogies with a social context and local background to bring chemistry to the learners' homes can be used as explained by Harrison and De Jong (2005). Many educators try to use several analogies although some of them have alternative conceptions to the scientific concept being demonstrated, for example: *"pour water in a cup until equilibrium is reached."* Several analogies are proposed for the basic concepts of chemical equilibrium. When using analogies clear parameters of observation should

be made and where the analogy breaks down, it should be clarified in order to negotiate the conceptual outcome (Harrison and De Jong, 2005). Learners should always be given opportunities to come up with their own analogical models to show an understanding of the concepts. A clear explanation of where the analogy links with the concept has to be clear.

As a way of trying to reduce the knowledge gap in learners CA₁ and CA₂ recommend re-deployment of educators in schools such that the qualified physical science educators can also teach at the GET band. The CAs believe this will help in building a solid base since it is seen that the major problems which are learner centred result from lack of basic knowledge.

5.3 Limitations of the study

Research population was limited to Thohoyandou Cluster of circuits where only 18 schools participated in the research. Statistics from the Education District showed that there were supposed to be 112 Physical Sciences educators comprising of qualified and unqualified ones. This study made use of the qualified Chemistry educators and this eventually reduced the population and sample. Only Chemistry educators who meet the minimum conditions for teaching at the FET band (Appendix 1) took part in the research.

During data collection process several challenges were encountered, for example: data collection was postponed along the line due to Public Service industrial Action during the month of August and September 2010. Much of the needed attention from educators was not received as they were struggling with high work load while they tried to cover the backlog due to industrial action in addition to preparation for grade 12 examinations.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

Teaching the concepts of chemical equilibrium proves to be a challenge to many educators and these problems appear through different manifestations in the learners like a lot of alternative conceptions, lack of interest in the subject (Chemistry) especially the topic, failing to apply the concepts to real life situations and also failing to integrate the topic with other topics and other subjects. These are just a few of the different observable manifestations. A variety of problems on teaching the concepts have been identified and the prospects of teaching the concepts were identified with recommendations in line with the observed problems.

It can be concluded that the major problems of teaching the concepts of chemical equilibrium lie in the understanding, explaining and demonstrating the basic concept of chemical equilibrium. These basic concepts are incompleteness of reaction, reaction reversibility, chemical dynamics and equilibrium constant. There are several alternative conceptions in educators on key terms which are used to explain the basic concepts of chemical equilibrium. Instead of key terms like system, open and closed system, shift, equilibrium, constant and state of balance being applied after developing the concepts, these are applied as raw English words without scientific meaning just as the textbooks used by both educators and learners fail to explain the key terms. This contributes significantly to alternative conception formation in learners.

The deficiency in topic content knowledge is identified as a major problem to the teaching of the topic. Due to lack of topic content knowledge, educators become less confident in their teaching

and this contribute significantly to reduced learners' confidence and motivation in exploring the topic for conceptual understanding. The lack of motivation and exploration make learners memorize the concepts as they are only eager to pass the national examinations without making sense out of the topic.

The educators demonstrated lack of pedagogical skills on new teaching strategies. Although there are efforts to use practical demonstrations and group work, the educator still remains the centre of the whole learning process instead of directing the process. Teaching is more of being educator-centred than learner-centred. Research findings show a lot of disparities between level of research in chemical education on new teaching techniques to improve the quality of teaching and current practices in schools. Educators still continue to use conventional methods while researches are showing improved strategies of teaching. Research still remains more of being academic than being practical as it is not involving more the educator who is supposed to implement the proposed strategies.

High educator-learner ratio is a problem as the educators do not have the necessary skills to use teaching strategies that are suitable for all learners' requirements. They rather use lecturing method in order to cope with the high number of learners per class. They generally employ exposition method supported with a few practical demonstrations and group work with questions and answers which are just extensions of conventional method of teaching.

English language being a second or third language to most of the learners made them to have a haze understanding of the language resulting in communication breakdown between educator-learner and learner-subject (Chemistry). This leads to reduced interest of learners in the subject especially to the abstract concepts of chemical equilibrium thereby making it more difficult for

the educator to employ the strategy which he finds suitable for conceptual and skills development in learners. Instead of the educator focusing on science process skills, the educator focuses on the learners getting information which can only make them pass the national examinations.

There is over-dependence on the textbooks by the educators to the extent that learners perceive chemical equilibrium as a textbook based concept which cannot be applied in real life. Learners are therefore not able to contextualize the taught concepts. Though the educators appeared to be solely depending on textbooks without consulting other sources of information like the scientific journals, credible web sites of the internet, they do not have textbooks with adequate and relevant information to address questions that come into national examinations especially the higher order questions. There is very little effort from educators to outsource relevant information which can make the learners see the relevance of the concept of chemical equilibrium.

The prospects of teaching Chemical Equilibrium hinge on In-Service Training of educators on topic content knowledge and developing pedagogical skills on new teaching strategies or techniques. Provision of laboratory equipment to schools and developing skills in educators of how and when to use the equipment is a key to improving the quality of teaching. Documenting problems and prospects of teaching any Chemistry topic is viewed as a way of assisting those educators particularly those that are struggling in teaching the basic concepts. Making reference to the proposed solutions of the problems of teaching chemical equilibrium by educators reduces alternative conceptions passed by them to the learners and minimises the recycling of the same set of problems from one generation to the other when teaching the same topic.

Problem-Solving strategy is well advocated for by educators as most of them assume to be using it, yet they only give learners many problems to solve. In most cases learners use the algorithm method which only applies to simple problems. Problem-Solving strategy that promotes conceptual understanding should be used. The conceptual understanding Problem-solving is demonstrated by the integration of multiple concepts, scientific rules, laws and principles of science to solve a single problem.

6.2 Recommendations

It is recommended that there should be a strong integration between the GET and the FET bands in terms of educator-participation and not only in the content matter. GET educators should be re-trained in a way that they are able to teach science “effectively” and provide a firm foundation for the Physical Sciences at the FET band. There is need to re-deploy educators equitably to both the GET and FET bands within the school, and not to only deploy the qualified science educators to the FET band. This re-deployment is meant to develop the basic science inquiry skills at a lower level which will be applied at higher levels like the FET band, Tertiary level and real life situations. Constant and continuous use of scientific language and permanent consolidation of information might reduce the communication breakdown between learner and the topic of chemical equilibrium and other chemistry topics.

There is need for In-Service Training of educators on problem-solving based on Wheatley model (1984) which this present researcher modified to appear as follows:

Proposed Modified Model for Problem Solving

- Read the problem
- Now read the problem again

- Read the question item while looking for key/ terms words
- Identify the topic to which the question falls under
- Identify the concepts to which the key words are related
- Write down what you hope is the relevant information
- Draw a picture, make a list, or write an equation or formula to help you begin to understand the problem
- Look for relationships and their explanations
- Try something else
- See where this gets you
- Read the problem again
- Try something else
- See where this gets you
- Test intermediate results to see whether you are making any progress toward an answer
- Read the problem again
- When appropriate, write down “an” answer (not necessarily ‘the answer’)
- Test the answer to see if it makes sense
- Start over if you have to, celebrate if you don’t.

Extract from U.Chem.Ed. Bodner, 2003, 7, 41

On numerical problems, simple mathematical operations should be done without using the calculator. That will promote logical thinking in the learners because they will ask themselves what is it that they want to do and find rather than just punching figures in the calculator get numerical values which they are not able to interpret and explain how and why.

Experimental demonstrations can be used, especially using the POE strategy. To avoid the use of irrelevant and confusing experiments for the learners, the Department of Education would usually recommend sets of experiments for specific concepts although they are not an end of the beginning. These are chosen on the basis of being simple and parameters of observation being 'clear' for the elements of chemical equilibrium. In-Service Training of educators on how to conduct these experiments and the pedagogical aspects of each experiment should to be included in the package. The following are samples of basic concepts and the experiments selected for each concept:

Reaction Reversibility

- Boiling water in a closed container
- Warming NH_4Cl in a closed test tube and use wet red and blue litmus paper
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

Reaction Incompleteness

- Boiling water in a closed container
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

Chemical Dynamics factors:

Effect of concentration on chemical equilibrium position

- $\text{Cr}_2\text{O}_7 / \text{CrO}_4^{2-}$
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

Effect of temperature on chemical equilibrium position

- $\text{NO}_2 / \text{N}_2\text{O}_4$
- $\text{CoCl}_4^{2-} / \text{Co}(\text{H}_2\text{O})_6^{2+}$

Effect of pressure on chemical equilibrium position

- $\text{NO}_2 / \text{N}_2\text{O}_4$

DoE, (2009)

On key terms of chemical equilibrium like system, open system, closed system, equilibrium, state of balance, shift, constant and others it is recommended that learners define and explain them in their note books as part of introduction of the topic. Educator only monitors to see that learners tried to explain the terms but does not give them the correct definitions or explanation or any guidelines until they have all made some attempts. Educator instructs the learners to revisit their definitions as they meet these terms during the topic. This gives the learners the chance to compare his English or ordinary language meaning of the term and how it is used scientifically, this might promote cognitive conflict within the learner leading to learning.

Regular In-Service training should be conducted after needs analysis has been done within the target group in order for the educators to make their contributions to the training. There should be a well structured training package on content knowledge and the pedagogical aspects of teaching chemical equilibrium to be used on the educators by specialists. Introduction of the key terms relating the basic concepts of chemical equilibrium using the problem-solving approach should form part of the training. Recommended experimental demonstrations should be

conducted by all educators during the training with the key points like parameters of observation for each particular concept and experiment well highlighted.

It is recommended that research results such as these find their ways into the classroom through professional bodies or research journals distributed to schools as part of material resources. Areas found for further researches are establishing the level of understanding and practice of learner-centred teaching strategies by educators. Another area for further research can be how to close the gap between chemistry education researches and what is happening in the classroom. Maybe this may reduce the cyclic pattern of same problems of teaching a particular topic being experienced from one generation to the other.

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APPENDIX 1: Minimum Requirements for Educators to Teach the Further Education and Training Band (Grade 10 – 12)

- A study of one or more subjects or specializations suitable for the phase.
- The study must include the disciplinary bases of content knowledge, methodology, and relevant pedagogic theory.
- The above specialist requirements should carry the following credits:

DE 36 credits at NQF 6, 60 credits at NQF 5 or higher

BED 96 credits at NQF 6, 108 credits at NQF 5 or higher

PGDCE 20 credits at NQF 6.

Extract from ELRC (A – 69)

APPENDIX 11: Ethical Clearance Letter



2 June, 2011

Mr. Marumure, G.P.

South Africa

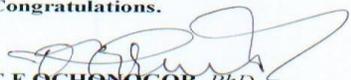
Dear Mr. Marumure,

REQUEST FOR ETHICAL CLEARANCE: Problems and Prospects of Teaching Chemical Equilibrium at the FET Band

Your application for ethical clearance of the above study was considered by the ISTE sub-committee on behalf of the Unisa Research Ethics Review Committee on 20 January, 2011.

After careful consideration, your application is hereby **approved** and hence you can continue with the study at this stage.

Congratulations.


C E OCHONOGOR, PhD
CHAIR: ISTE SUB-COMMITTEE

cc. **PROF T S MALULEKE**
EXECUTIVE DIRECTOR: RESEARCH

PROF M N SLABBERT
CHAIR- UREC.



APPENDIX 111: Letter to District Senior Manager

ENQ: MARUMURE G.P.

CELL No. 0797038403

THOHOYANDOU TECHNICAL HIGH

P.BAG X2597

SIBASA, 0970

16 APRIL 2010

THE DISTRICT SENIOR MANAGER

VHEMBE DISTRICT

P.BAG X2250

SIBASA, 0970

**REF: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH IN
THOHOYANDOU CLUSTER OF VHEMBE DISTRICT OF LIMPOPO PROVINCE.**

I am an educator at the above mentioned school and currently studying for a Master degree with UNISA in Science, Mathematics and Technology. My learner number is 45074909.

The major component of the study is to carry out a research, therefore I am requesting for permission to conduct a research in the five (5) circuits of Thohoyandou cluster. The topic of study is: **PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FET BAND.** The research involves distributing questionnaires to selected schools, interviewing some of the Physical science educators at the FET band and the subject advisors. Also some documents with relevant information may be requested from district office, circuit offices and schools may be requested. Period of research is April 2010 to 2011.

Your cooperation is greatly appreciated.

Yours faithfully

Marumure G.P.

APPENDIX 1V: Clearance Letter from Vhembe District

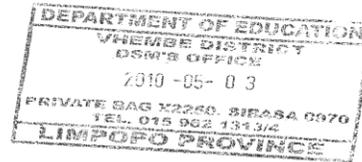


LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

Ref: 17/2/2/P
Enq: M.S. Matibe
Tel: 0159621029

DEPARTMENT OF
EDUCATION
VHEMBE DISTRICT

Mr. G.M. Marumure
Thohoyandou Technical High School
Private Bag X2557
Sibasa
0970



REQUEST TO CONDUCT A RESEARCH IN THOHOYANDOU CLUSTER OF CIRCUITS: VHEMBE DISTRICT

1. The above-mentioned matter bears reference.
2. Your request for permission to conduct a research on the topic: "problems and prospects of Teaching Chemical Equilibrium at the FET Band" in five Circuits of Thohoyandou Cluster has been approved.
3. Kindly inform Circuit Managers and Principals of affected schools about your intended visits well in advance.
4. You are further advised to ensure that your interactions with educators during your visits do not disrupt teaching and learning activities.
5. Wishing you the best in your quest for academic achievement.


DISTRICT SENIOR MANAGER

03/05/2010
DATE

Thohoyandou Government Building, Old Parliament, Block D, Private Bag X2250, SIBASA, 0970
Tel: (015) 962 1313 or (015) 962 1331, Fax: (015) 962 6039 or (015) 962 2288

The heartland of southern Africa - development is about people!

APPENDIX V: Letter to Circuit Manager

ENQ: MARUMURE G.P.

CELL No. 0797038403

THOHOYANDOU TECHNICAL HIGH

P.BAG X2597

SIBASA

0970

.....

THE CIRCUIT MANAGER

.....

.....

REF: REQUEST TO DISTRIBUTE AND COLLECT RESEARCH QUESTIONNAIRES TO AND FROM SCHOOLS THROUGH YOUR OFFICE.

I am an educator at the above mentioned school and currently studying for a Masters degree with UNISA in Science, Mathematics and Technology Education.

I kindly request you to assist me with the distribution and collection of my research questionnaires to and from schools in your circuit through your office. The topic of study is: **PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FET BAND.**

Please find attached a letter of authorisation from Department of Education Vhembe district to conduct the research.

Your cooperation is greatly appreciated.

Yours faithfully

Marumure G.P.

APPENDIX V1: Letter to School Principals

ENQ: MARUMURE G.P.

CELL No. 0797038403

THOHOYANDOU TECHNICAL HIGH

P.BAG X2597

SIBASA

0970

.....

THE PRINCIPAL

.....

.....

REF: REQUEST TO DISTRIBUTE AND COLLECT RESEARCH QUESTIONNAIRES TO AND FROM PHYSICAL SCIENCE (CHEMISTRY) EDUCATORS.

I am an educator at the above mentioned school and currently studying for a Masters degree with UNISA in Science, Mathematics and Technology Education.

I kindly request you to assist me with the distribution and collection of my research questionnaires to and from Physical Science (Chemistry) educators at your school. The topic of study is: **PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FET BAND.** You are requested to submit the completed questionnaires to the circuit office within 5 working days from the day they were collected from the circuit office.

Please find attached a letter of authorisation from Department of Education Vhembe district to conduct the research.

Your cooperation is greatly appreciated.

Yours faithfully

Marumure G.P.

APPENDIX VI1: First Draft Questionnaire

Godfrey Pisirai Marumure is a student at UNISA and is conducting a research in Vhembe District of Limpopo Province on *Problems and Prospects teaching the Topic on Chemical Equilibrium at Further Education and Training (FET) Band*. The research may assist when designing professional development activities; therefore you are requested to attempt answering all the questions in good faith. Contact Number: **0797038403**

PERSONAL INFORMATION

Mark with an **X** in the appropriate box

Gender: Male Female

Age 20 – 25 26 – 30 31 – 35 36 – 40 41 – 45 46 – 50 51 >

Teaching Experience 0 – 5 6 – 10 11 – 15 16 – 20 21 – 25 26 >

Number of years at school:

Number of years teaching Grade 12 Chemistry:

Academic Qualification:

Where obtained:.....

When obtained:

Professional Qualification and specialization	Where obtained	When obtained
E.g. BED (Chemistry)	University of Venda, SA	2002

Any other qualifications:

.....
.....
.....

Other relevant information:

.....
.....
.....
.....

SCHOOL INFORMATION

Type of school: Rural Urban Semi-urban/ semi rural

School enrolment:

Physical science enrolment per grade

Grade	Enrolment	Number of classes
10		
11		
12		

School staff enrolment:

Number of Physical Science educators:

Average teaching load of science educators:

Does the school have a science laboratory:

Comment on the availability of apparatus at your school:

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Other relevant information:

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.....

GENERAL INFORMATION

Which grade are you comfortable with at FET.

Give a reason

.....
.....
.....

Rank the Grade 12 Chemistry topics: put a tick in the table

	Very Comfortable	comfortable	Uncomfortable	Very uncomfortable
Chemical Change				
Electrochemical cells				
Equilibrium				
Rates of reaction				

Comment your ranking on chemical equilibrium.

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What are the major challenges encountered during the lessons on chemical equilibrium.

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Generally how long do you take preparing your lessons on the topic?

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Which text books do you use as references?

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Which text books are used by learners?

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Comment on the textbooks in respect to the topic in question. Are you satisfied?

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When teaching the topic what are your major concerns as a chemistry educator?

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How do you improve your pedagogical content knowledge?

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What recommendations can you make on the teaching of the topic chemical equilibrium?

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Any other relevant information which you want to share?

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END: Thank you!!!

APPENDIX VIII: Final Draft Questionnaire

Godfrey Pisirai Marumure is a student at UNISA and is conducting a research in Thohoyandou Cluster in Vhembe District of Limpopo Province on **Problems and Prospects of Teaching Chemical Equilibrium at FET band**. The research is intended to assist educators, curriculum advisors, material developers, when designing professional development activities and producing resource materials.

You are kindly requested to complete this questionnaire. Contact Number: **0797038403**

A. PERSONAL INFORMATION

Mark with an **X** in the appropriate box

1. Gender: Female Male

2. Age range (tick appropriate box)

20 – 25	26 – 30	31 – 35	36 – 40	41 – 45	46 – 50	<50
<input type="checkbox"/>						

3. Teaching Experience	0 – 5	6 – 10	11 – 15	16 – 20	21 – 25	< 25
	<input type="checkbox"/>					

4. Professional Qualifications and area of specialization:

.....

B. SCHOOL INFORMATION5. Type of school: Rural Urban Semi- urban/ semi rural

6. School Physical science enrolment per grade

Grade	Enrolment	Number of classes
10		
11		
12		

7. Number of Physical Science educators:

8. Does the school have a science laboratory? Yes or No

9. Comment on the availability of chemistry laboratory apparatus at your school:

.....

C. TEACHING OF CHEMICAL EQUILIBRIUM 10. Indicate your feeling when teaching

basic concepts of chemical equilibrium reactions below: put a tick in the table

Item	Very Comfortable	comfortable	Uncomfortable	Very uncomfortable
Reaction Incompleteness				
Reversibility of reaction				
Chemical dynamics				
Equilibrium constant				

11. Generally, how long do you take preparing your lessons on the topic? Tick range.

0 – 10 11 – 20 21 – 30 31 – 40 more than 40 minutes

12. List commonly used text books by teacher and learners.

Teacher:

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Learners:

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13. Comment on the teachers' and learners' textbooks in respect to the topic in question. Are you satisfied?

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14. Which method/ strategy do you employ to teach specific concepts of chemical equilibrium?

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15. May you give a short description of your lesson procedure, specify each concept on chemical equilibrium

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16. How do you incorporate learners' prior knowledge in your lessons?

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17. List any experiments/ demonstrations you conduct when teaching concepts of chemical equilibrium? (Prioritise)

- i.
- ii.
- iii.
- iv.
- v.

18. Indicate any special activities done during lessons and their sources?

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19. What do you consider to be the major challenges/ problems when teaching concepts of chemical equilibrium?

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20. What are the possible causes of the mentioned problems?

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21. What are the possible effects of such problems on students' performance in chemistry?

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22. How do you solve these problems you encounter on teaching concepts of Chemical Equilibrium?

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23. During the past 5 years have you ever got any support on the teaching of chemical equilibrium? Yes/ No.....

24. If yes, what kind of support and who provided it?

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25. How do you share information on new teaching strategies with colleagues?

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26. May you give a short description of your innovations on improving the teaching of chemical equilibrium?

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27. May you give a short description of the new/ latest strategies which can be used to teach a specific concept on chemical equilibrium?

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28. How can the quality of teaching Chemical Equilibrium be improved in order to improve learners' performance?

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29. What are the prospects of teaching concepts of chemical equilibrium in order to improve the quality of teaching and improve learners' performance?

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30. Any other relevant information on the teaching of chemical equilibrium which you want to share?

.....
.....

Thank you for participating in the exercise.

SC 38 T2

APPENDIX VIII QUESTIONNAIRE

Godfrey Pisirai Marumure is a student at UNISA and is conducting a research in Thohoyandou Cluster in Vhembe District of Limpopo Province on *Problems and Prospects of Teaching Chemical Equilibrium at FET band*. The research is intended to assist educators, curriculum advisors, material developers, when designing professional development activities and producing resource materials.

You are kindly requested to complete this questionnaire. Contact Number: **0797038403**

A. PERSONAL INFORMATION

Mark with an X in the appropriate box

1. Gender: Female Male
2. Age range (tick appropriate box)
- | | | | | | | |
|--------------------------|--------------------------|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 20-25 | 26-30 | 31-35 | 36-40 | 41-45 | 46-50 | <50 |
| <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
3. Teaching Experience
- | | | | | | |
|--------------------------|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 0-5 | 6-10 | 11-15 | 16-20 | 21-25 | <25 |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
4. Taught Chemistry at FET band between 2005 and 2010. YES/ NO. YES
5. Professional Qualifications and area of specialization:
..... BACHELOR OF SCIENCE WITH EDUCATION (CHEMISTRY BIOLOGY)

B. SCHOOL INFORMATION

6. Type of school: Rural Urban Semi-urban/ semi rural
7. School Physical science enrolment per grade

Grade	Enrolment	Number of classes
10	290	4
11	240	4
12	177	3

8. Number of Physical Science educators: 5

9. Does the school have a science laboratory? Yes or No ... Yes

10. Comment on the availability of chemistry laboratory apparatus at your school:

The laboratory have got basic apparatus which are very few for the large classes. Demonstration method is only used which is not effective for the large classes.

C. TEACHING OF CHEMICAL EQUILIBRIUM

11. Indicate your feeling when teaching basic concepts of chemical equilibrium reactions below: put a tick in the table

Item	Very Comfortable	comfortable	Uncomfortable	Very uncomfortable
Reaction Incompleteness		✓		
Reversibility of reaction		✓		
Chemical dynamics		✓		
Equilibrium constant	✓			

12. Generally, how long do you take preparing your lessons on the topic? Tick range.

0 - 10 11 - 20 21 - 30 31 - 40 more than 40 minutes ✓

13. List commonly used text books by teacher and learners.

Teacher: Study and Master

Focus on Physical Science

Learners: Physical Sciences Explained, Jones et al.

Study and Master

14. Comment on the teachers' and learners' textbooks in respect to the topic in question. Are you satisfied?

Some of the textbooks does not clearly show how K_c is calculated, they just put tables with figures, so learners tend to wonder how they got the figures.

15. Which method do you normally use to teach specific concepts of chemical equilibrium?

Factors affecting Equilibrium — Demonstration but if apparatus and chemicals are available learners do the experiments.

on their own

Calculation of K_c and Le-Chatelier's Principle — Problem solving method.

16. May you give a short description of your lesson procedure, specify each concept on chemical equilibrium

Introduction — by asking learners to define terms like reversible reaction, concentration, pressure, catalyst.
Teacher — Pupil discussion on Chemical Equilibrium.
Demonstration illustrating chemical Equilibrium, and effects of concentration, pressure and temperature on chemical equilibrium.

17. How do you incorporate learners' prior knowledge in your lessons?

By asking questions or by making a mini-quiz.

18. List any experiments/ demonstrations you conduct when teaching concepts of chemical equilibrium? (Prioritise)

1. Effects of Concentration on Chemical Equilibrium (Cobalt Chloride)
2. Effect of Pressure: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ observing colour change.
3. Effects of Temperature.

19. Indicate any special activities done during lessons?

Group work — to do some experiments and to solve problems to apply Le-Chatelier's principle.
Individual work on calculation of K_c .

20. What are the main sources of learner activities?

Textbooks and Past Exam papers.

21. What do you consider to be the major challenges/ problems when teaching concepts of chemical equilibrium?

Most learners have problems in Maths, so they are not able to do some calculations. Learners are not able to apply Le-Chatelier's Principle.

Some learners do not understand English

22. What are the effects of such problems on students' performance in chemistry?

Learners believe more in what is in the

23. During the past 5 years have you ever got any support on the teaching of chemical equilibrium?

Yes/ No... Yes

24. If yes, what kind of support and who provided it?

Hand outs from Curriculum advisers
Intervention Guides

25. How do you share information on new teaching strategies with colleagues?

Through discussions at workshops or by inviting another teacher to observe my lesson

26. May you give a short description of your innovations on improving the teaching of chemical equilibrium?

27. May you give a short description of the new/ latest strategies which can be used to teach a specific concept on chemical equilibrium?

By making use of Audio-visual teaching aids or the internet, learners have more interest in new Technology, so making use of these might motivate them.

28. What are the prospects of teaching concepts of chemical equilibrium in order to improve the quality of teaching and improve learners' performance?

.....
.....
29. Any other relevant information on the teaching of chemical equilibrium which you want to share?

More questions should be given to learners for them to practise

Thank you for participating in the exercise.

APPENDIX X: Letter to the chemistry educators.

ENQ: MARUMURE G.P.

CELL No: 0797038403

THOHOYANDOU TECHNICAL HIGH SCHOOL

P. BAG X2597

SIBASA

0970

24 April 2010

Dear sir/ Madam

REF: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH INTERVIEW WITH YOU.

I am an educator at the above mentioned school and currently studying for a Masters degree with UNISA in Mathematics, Science and Technology Education. In order to meet the requirements of the degree programme I am expected to conduct some research interview and submit a full dissertation related to this.

I therefore request for an interview with you. My topic of study is **PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FET BAND**. This requires me to interview educators of Chemistry at the FET band. I also request that the Interview be tape recorded to save time and ensure that I do not miss valuable information during the conversation. I assure anonymity and confidentiality of every response you will make.

Your cooperation is greatly appreciated.

Yours faithfully

Marumure G.P.

APPENDIX XI: Interview Schedule for Chemistry educators

Introductions

Purpose of interview

Interview procedure

Interview

1. How long have you been teaching chemistry at the FET band?
2. Does your school have a science laboratory?
3. How equipped is it?
4. Generally how long do you take preparing your lessons on chemical equilibrium?
5. Which text books do you use as references?
6. Which text books are used by learners?
7. Are you satisfied with them?
8. Which method do you use to teach?
 - I. Incompleteness of reaction
 - II. Reversibility
 - III. Chemical dynamics
 - IV. Equilibrium constant.

9. May you give a short description of how you teach the above concepts?
10. In what way do you accommodate learners' prior knowledge in your lessons?
11. Which laboratory experiments/ demonstrations do you carry out when teaching the above concepts?
12. Are there any special activities done during your lessons? Which are these?
13. What are the major sources of these learner activities?
14. What do you consider to be the major challenges or problems when teaching the concepts of chemical equilibrium?
15. How much support have you got on the teaching of chemical equilibrium?
16. What are some of the learners' problems on chemical equilibrium? Any reason for these problems?
17. What are the prospects of teaching chemical equilibrium in order to improve the quality of teaching and improve learners' performance?
18. In what way do you share information on new teaching strategies with colleagues?
19. Any other information which you might want to share on the teaching of chemical equilibrium?

Thank the interviewee and promise to furnish him/ her with results and recommendations of research.

THE END

APPENDIX XII: Sample Interview with Chemistry Educator (T1)

Profile of Educator: 20 Years experience teaching Chemistry. Results during the last 3 years: 2008 NSC Grade 12 Physical Science 95%; 2009 NSC Grade 12 Physical Science 94%; 2010 NSC Grade 12 Physical Science 100% pass.

INTERVIEW PROCEEDING:

Venue: Deputy Principal's Office. **Date:** 08/03/2011. **Time:** 1400- 1430hrs.

Q: Question by interviewer. R: Response by Educator.

INTERVIEW

Interviewer: I understand you have been teaching for a long time (interjection: *yes*). I am studying with UNISA and the programme I am doing requires me to conduct a research therefore I am collecting research data on Problems and Prospects of teaching Chemical Equilibrium at FET band so that I can come up with a document on how to deal with these problems. Mainly our problem in teaching is that when someone retires, regardless years of experience, this is not shared by novice educators. We are trying to come up with documents on the teaching of specific topics which can be referred to like what happens in chess, law and so forth. Since you have a lot of teaching experience I thought if I conducts an interview with you this might help me come up with such a document.

Q: For how long have you been teaching Chemistry?

R: It's almost 20 years teaching FET.

Q: Does your school have a science Laboratory?

R: We have improvised, no real laboratory, it was a kitchen where home Economics educator used to help learners. After the home economics had been dropped out, we used the room as a lab, equipment not enough but we are improvising, we do not have a real lab per se.

Q: But you are able to carry out basic experiments?

R: Yes, we are able to carry out basic experiments.

Q: Getting into the topic. Chemical Equilibrium is a topic which challenges learners. There how do you introduce such concepts as incompleteness of reaction?

R: To the learners when introducing incompleteness of reaction, I must tell them about factors which affect the rate of reaction. Because the incompleteness of reaction can be due to factors for example little amount of concentration can lead to incompleteness of reaction but if we put more concentration of the reactant, then we can have some completeness. I must make sure my learners understand about the factors that affect the rate of reaction. That is why I'm able to teach Chemical Equilibrium.

Q: Ok, the other one is reversibility of reaction.

R: On the reversibility of reaction, learners must understand about dynamic Equilibrium that it means the forward and the reverse reaction is equal therefore that is why it is reversible. It means the reaction will go to forward direction and thereafter it could reverse again. A child must know that this is dynamic equilibrium (interjection: dynamic Equilibrium). This is how it can be achieved.

Q: (Interjection: you have introduced new term, dynamic equilibrium; reversible reaction)

A: Yes

Q: When learners come to these classes they have some misconceptions. (Interjection: Yes). How do you clarify this especially on misconceptions on Chemical Equilibrium, Reversibility of reaction and so forth?

A: They think why can it reverse? That process must be in a closed container must be a closed system in such a way that reversibility must be achieved. Learners must understand that the reaction is taking place in a closed container such that no leakage must move out because we will never have reversible, it must be dynamic equilibrium that is why I must emphasise that if you want to achieve this reversibility it must be in a closed container it must be eehh... closed container, closed system.

Q: As now we are talking, speaking you are talking of closed container, closed system you are introducing new terms again to the learners (Interjection: Eehh, to the learners)?

A: Yes, now we are telling them new terms, it gives a brief understanding if the learners about the topic.

Q: Another challenge is when you look at text books which are used; they do not define words like system. How do you introduce these terms to the learners?

A: Some text books, because we don't have specific books for NCS, for our syllabi, we don't have specific type of text book, that is why we are using different type of text books but most of the systems will never show you whether the system is closed or open. They just say if the system is closed it means there is no leakage but open system cannot be dynamic equilibrium. When you teach a learner about this thing, closed system every reaction can take place. For

example reversible reaction nitrogen dioxide (NO_2) as a reactant will nitrogen tetraoxide (N_2O_4) as product it depends on the temperature, when temp go down will give N_2O_4 , it will change and go in another direction, factors are very important.

Q: You have been talking about system, closed system and now you are talking about shifting, this is where the complication comes in.

A: When talking of shift, equilibrium can shift to the right or to the left which falls under Le Chatelier's principle as indicated on your guide (program). Reaction can shift to the right or to the left according to Le Chatelier's principle; favour the left side or the right side. It depends on three aspects according to Le Chatelier's principle temperature, concentration and pressure. That is the most important part of shifting. A learner must understand now when we talk of shift, which favour it is going to shift; it also depends on the heat of reaction, if it is exothermic or endothermic. An increase in temperature will favour the endothermic and a decrease will favour the exothermic. Therefore according to the equation of reaction, we must show the learners ΔH is positive, the forward reaction is endothermic; if negative forward reaction is exothermic. Therefore when talking of shifting we must emphasise the Le Chatelier's principle.

Q: Ok, still on Chemical Dynamic and Equilibrium, Equilibrium constant (K_c) its significance?

R: Yes I understand, K_c is very difficult for learners, when you teach K_c the first thing to say is $K_c = \frac{[\text{product}]}{[\text{reactants}]}$ expression

How to teach it, the best way is to make a table write well the reactants and products, emphasis on reactants and products columns. Indicate column for initial, what has reacted or formed, column for the equilibrium and column for concentration, this is how a learner can understand this. If a learner does not understand the K_c expression it is difficult. Nowadays we prefer to

use a graphical or table form, that is the simplest way for learners to understand. All the reactants must be placed on top. You write on top the reactants on the left and products on the right, and from there you must indicate the initial, what happens in the initial, the number of moles in the initial must be given from the question. What happens to the initial must be very important for K_c . K_c is very difficult for learners.

Q: There is this aspect which you find in most of the text books $aA + bB \rightleftharpoons cC + dD$ and they use it to write the K_c expression. At the end when learners are asked to write the K_c expression they write for the above reaction instead of the given reaction. How do you deal with this problem?

R: No, when you explain you indicate that A , B , C and D are variables and they stand for the reactants and products, when you explain you must use examples and give a thorough explanation based on a complete reaction. From there you indicate the reactants and products and show them on my right are the products and on my left are the reactants. Therefore my $K_c = \frac{[\text{product}]}{[\text{reactants}]}$ where a and b are put as to the power. Learners omit the ratios which indicate to the power given.

Q: Ok, then again as we are talking of many concepts and so on we are talking of different levels, the macroscopic, microscopic and symbolic levels, how do you make learners understand as you jump from one stage (level) to another?

R: Macroscopic in which way, microscopic in which way?

Q: Normally when talking about reactions we are talking about parameters that we can observe, when it comes to equilibrium its very difficult to see any change although the reaction is taking place.

R: when you explain of equilibrium, for some reactions you can see the colour changes just like the reaction of NO_2 as reactants and N_2O_4 (Nitrogen tetraoxide) as the product. NO_2 as reactant is brown in colour and N_2O_4 as product is colourless. Therefore because of change of temperature it can go forward and reverse. They can see clearly in a clean clear container that is where they can see the forward and the reverse but you must emphasise that temperature is the factor being changed. Emphasise the effect of temperature.

Q: So right here you are talking of NO_2 and N_2O_4 as an experiment. Are there any other experiments that you conduct during the lessons?

R: Some of the experiments you cannot see the reverse part of it. It's impossible, that's why we say microscopic and macroscopic, we can't see, you can see the reactants but whether it is proceeding backward you need some testing type if it can get the product, mostly we can see.

Q: It means on experiments we have limitation there, besides this limitation any other method that you use e.g. analogies to explain these concepts so that learners do have a conceptual change because when learners when they come to class they have their own concepts?

R: Before you teach learners, they must have previous knowledge in such a way when you move to another part they must have a link from the previous knowledge. Now we are getting to this. In such a way it must link. This is another way of getting to know.

Q: How do you include their prior knowledge which they bring from their homes?

R: Prior knowledge, you ask them questions, some are intelligent they can explain what they know from their home place, from previous grades and also challenging questions on what they

were doing previous years, whether they know from previous lessons so that they have some link with what you are going to do especially when you are teaching chemical reaction.

Q: What I have realised is when teaching this topic, talking of Equilibrium e.g. this year introducing the topic i put words like equilibrium, system, open and closed system, reversible reaction, shift, constant and said define them. On equilibrium they were defining it in terms of Newton's Law of motion- Action and Reaction.

R: Yes, now on equilibrium you must explain Equilibrium in term of Chemical reaction, not equilibrium according to the Physics part. That equilibrium is another thought. Here we are moving with the rate of reaction, you explain thoroughly.

Q: As I explained that learners have problems, have you ever encountered any type of problems or challenges?

R: Learners have problems on rates of reaction and Equilibrium. Not able to realise whether is a forward and reverse, those factors confuse learners and also when we talk in terms of dynamic equilibrium when we include Le Chatelier's Principle, when temperature, pressure and concentration must be known by learners, that's why they get confused. The 1st thing is for the learners to understand the application of the Le Chatelier's Principle. That's why when we refer to Chemical Equilibrium we must have to understand the rate of reaction from the onset and factors and it will be easy for them.

Q: So the major cause of this problem is the understanding of the rate of the Reaction?

R: Yes, if learners do understand the rate of reaction it is easy to understand Chemical Equilibrium. That is the link.

Q: How do you try to solve some of these problems?

R: Mostly with learners, you must move with them, when you teach the aspect of rate of reaction you start with minute things. You know reaction is when two reactants react with one another and form a product. From there we talk in terms of the rate/ speed, from there we talk in terms of the factors, from the factors we realise about 5 factors concentration, temperature, catalyst, state of division and also ehhh pressure. It makes them to be aware of the factors. Now when we deal with the concept of Eq concentration you must understand the Kc expression and also the Le Chatelier's principle's application. Now it will be smooth running now from there you understand Reaction Equilibrium. You start from scratch, from rate of reaction deeply down until you reach Chemical Equilibrium. That is where you can change their mindset and make sure that they must understand, mind you they don't have any prior knowledge from Grade 11 they don't have anything and it's a new concept and you must treat it with caution.

Q: During the lessons are there any special activities?

R: Yes, during lessons we have special activities where we can demonstrate, we can make them calculate, or work together in groups and this make them aware and to involve them in each and every lesson we do it.

Q: Do you have any special source for those activities?

R: We don't have a source by now, we depend on the few textbooks we have. Those are the sources we can try to show the learners and work with learners.

Q: We can talk in terms of support from other sources like people, in terms of materials and so on.

R: Yes, we do have support, especially in the science department from the head of department, from the colleagues, but the major support is the resources, if we have more resources we have about 2 textbooks which we are using, one is Focus and the other is Study and Master. They are relevant but we need to have more detailed and much simpler to learners as it will help learners to use more text books. We don't have relevant text book now in this curricular; they are still trying to find relevant textbook for Chemistry and Rates of reaction. That is why we use different sources and try to make sure learners do understand about Chemical Equilibrium.

Q: Then from Subject Advisors (CA)?

R: Yes, they do come and advise us when we have problems, they advise us, use this text book or that one. I can buy it or as an educator show the learners or copy and distribute to learners, it will help. It is another type of resourcing we are improvising.

Q: Right now in different schools we are using different methods/ different strategies to teach this topic. What do you think is the way forward?

R: I realise one thing, we must have cluster of teachers who are teaching Chemistry, topics like Equilibrium, in such a way we have to do something which is similar in approach. This can be done only if we undergo some workshops, if we undergo some training, professional development in such a way we can start to master similar aspects in all clustering schools. When I refer to cluster I mean schools around same area e.g. Thohoyandou Cluster. If all educators can come together and make a meeting of some sort and we discuss about the approach and how we can teach some topics, we can make it at the end of the year, have different performance from learners at the end of the year.

Q: That is the major way forward?

R: Yes, have teachers who have got an idea or vision like me of professional development, we come together, help one another, teach one another on different topics especially in Chemistry because learners are failing hopelessly. I'm just saying the government can help in, we can make clusters and also In-service training is needed because this is a new curriculum. Most of the topics are new therefore it needs us to be capacitated. (Interjection: In-Service Training first train the trainer). Yes, train ourselves in order to train others, we can start with small clusters from there we can just go and train the educators. It must be uniform when we teach the topic, there must be uniformity. That's how we can manage to help learners from different sphere whether it's rural or urban it will be the same.

Q: I do agree with you because I have realised sometimes after teaching learners and when they come back from Saturday schools from other schools they try one or two things which are different from what I taught them and they get confused.

R: We need In-Service training, workshops and professional development for all educators to have a uniform approach on a topic.

Q: This is what we trying to do because even Circuit Managers are aware that I'm moving around schools collecting such information such that at the end we may come up with a document which may help us besides the research being for study purpose.

Thank you sir for giving me your time. We have come to the end of our interview. Thank you once again.

APPENDIX X1III: Letter to Physical Science Curriculum Advisors.

ENQ: MARUMURE G.P.

CELL No: 0797038403

THOHOYANDOU TECHNICAL HIGH SCHOOL

P. BAG X2597

SIBASA

0970

24 April 2010

Dear sir/ Madam

REF: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH INTERVIEW WITH YOU.

I am an educator at the above mentioned school and currently studying for a Masters degree with UNISA in Mathematics, Science and Technology Education. In order to meet the requirements of the degree programme I am expected to conduct some research interview and submit a full dissertation related to this.

I kindly request for an interview with you. My topic of study is **PROBLEMS AND PROSPECTS OF TEACHING CHEMICAL EQUILIBRIUM AT THE FET BAND**. This requires me to interview educators of Physical Science Subject Advisors of Thohoyandou Cluster. I also request that the interview be tape recorded to save time and ensure that I do not miss valuable information during the conversation. I assure anonymity and confidentiality of every response you will make.

Your cooperation is greatly appreciated.

Yours faithfully

Marumure G.P.

APPENDIX XIV: Interview schedule: Physical Science Subject Advisors

- Introductions
 - Purpose of interview
 - Expectations
1. Sir, for how long have you been CA for the cluster?
 2. May you give a short description in terms of resources in your cluster mainly referring to:
 - a. Human resources
 - b. Text books resources
 - c. Laboratory resources
 3. Are satisfied?
 4. Chemical equilibrium is a very important concept in Chemistry. What is your comment on how the topic is taught in schools?
 5. How do the educators teach the following concepts of chemical equilibrium?
 - a. Incompleteness of reactions
 - b. Reaction reversibility
 - c. Chemical dynamics
 - d. Equilibrium constant?

6. What do you view as problems when teaching concepts of chemical equilibrium?
7. What are the effects of these problems on learners' performance?
8. What are your suggestions of how these concepts should be taught in order to improve learners' performance?
9. Have you ever organised professional development activities on the teaching of chemical equilibrium in the last 5 years?
10. How prepared are educators to implement new teaching strategies/ methods on the topic?
11. Evaluating the educators' innovations and their preparedness on new teaching strategies, what is the future of teaching chemical equilibrium?
12. In conclusion any new method which can be used to teach the above concepts or any concept on chemical equilibrium?
13. Finally any information on the teaching of chemical equilibrium you may want to share?

APPENDIX XV: Interview with CA₁

Date: 25 October 2010. **Venue:** Bergvlam Primary School Hall. **Time:** 1450 -1530

Introduction: I'm a student at UNISA, under the ISTE. The ISTE focus on effective teaching and learning of Science, Maths and Technology in schools. Currently I am conducting a research on one of the topics in Chemistry which is Chemical Equilibrium in Thohoyandou Cluster of schools. Investigating the problems and prospects of teaching the concepts of Chemical Equilibrium at FET band, since data is collected from educators you are directly working within the cluster I felt it necessary to have an interview with you on the topic. Findings from this research may help us to find solutions to some of the problems. During the interview follow up questions may be asked basing on information already collected from the educators.

Interview

Interviewer (I): Sir, for how long have you been CA for the Cluster?

Respondent (CA): Only two and half years.

I: May you give a short description in terms of Resources in your cluster mainly referring to: Human Resources, Textbooks and Laboratory Resources.

CA: There is a serious shortage because I am doing work for 3 or 4 people. Each circuit is supposed to have its subject advisor for the subject but at the moment we are only 2. There is a big shortage of Physical science educators. Educators are under qualified to teach FET. In some schools you find educators who trained to teach languages being given Natural Sciences Grade 8 and 9 to teach. The few who are there specialised in either Physics or Chemistry and are qualified to teach only one paper, either paper 1 or 2.

There is only one school with a laboratory which is fully equipped. 10% have partial labs, the rest do not have labs at all.

There are textbooks in schools but these textbooks do not cover the syllabus adequately therefore there is no recommended textbook for the syllabus. Most of the textbooks were written in 2004-5 before the new syllabus, when the syllabus was released publishers did not come up with new textbooks for the syllabus. With the new changes being advocated on the NCS the publishers are now waiting for the changes to come up with the new textbooks.

I: Chemical Equilibrium is a very important concept in Chemistry? What is your comment on how the topic is being taught in schools?

CA: Not properly taught.

I: How do educators teach the concepts of Chemical Equilibrium like reaction incompleteness, reaction reversibility, chemical dynamics and equilibrium constant?

CA: Some educators do not even understand these concepts which you are talking about, then how do you expect them to teach them. Checking learners' books, you can see that notes are just copied and an example in the textbook is repeated without any additions. They only teach to cover the syllabus and some just read what is in the textbook. It is only in a few schools where you see that varied method of teaching are used. Experiments are done; class work is given where learners are asked to solve the problems. Learners do not have basic science skills when coming to the FET band as a result this discourages the educators.

I: What are the possible causes of these problems?

CA: Educators lack the content knowledge since they are under qualified. Also as I said before educators who are assigned to teach grades 8 and 9 did not do any science at tertiary as a result the learners when they get to FET band they lack basic science skills. Also the type of training some educators went through; it did not give them the confidence to do experiments.

I: With all these problems, what do you see as effects to learners' performance?

CA: Low percentage pass rates, with some even getting 0%. Those schools where such topics are taught well are doing very well. Some getting 100% pass rate although they are few.

I: As educators are struggling, what are your suggestions on how these concepts should be taught in order to improve learner performance?

CA: Educators should prepare more materials and handouts. The concepts should be contextualised so that learners can easily understand. Educators should only guide the learners, during a 1 hour lesson, the educator should talk for a maximum of only 20 minutes and the remaining 40 minutes learners should be solving given problems. Not all work should be marked by educator; learners can mark their books with guidance from the educator. Educator should only check the learners' books to see if they are doing the right thing after a week and checking learner progress.

I: With all these problems, have you ever organised professional development on the teaching of chemical equilibrium?

CA: No. Not at all.

I: Why, when this topic constitutes more than 33 marks out of 150 in the final Grade 12 Paper 2 examination?

CA: Content workshops have been organised for other topics which are more problematic to the educators like the Organic Chemistry. Even at the MASTEC where CAs were taught the new content this topic was not treated.

I: What is the future of the teaching of the concepts of Chemical Equilibrium?

CA: Content workshops to be organised in order to empower educators. There should be orientation of new educators on the new curriculum as it is found that some do have the content but they are not teaching the content according to the requirements of the curriculum. More teachers for Physical Science should be trained. If it is possible educators who did science should teach the GET band so that when learners reach the FET band they do have basic science skills.

I: Do you advise school principals on the allocation of classes to educators?

CA: At times when necessary, especially when they have many science educators.

I: In conclusion, any information which you may want to share on the teaching of Chemical Equilibrium?

CA: Schools should provide basic resources for the teaching of science. The topic should be allocated more time, maybe 2 weeks.

I: Thank you for allowing me to have your time during the interview. I will furnish you with the results of the research since you are working directly with the educators. I hope this may help you when planning professional development activities for educators in your cluster.

THE END

